

The University of Chicago

CAUSES OF ANNUAL FLUCTUATIONS
IN THE PRODUCTION OF LIVESTOCK
AND LIVESTOCK PRODUCTS

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE SCHOOL OF BUSINESS IN CANDIDACY
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

1947

By
JAMES H. LORIE

Reprint of
STUDIES IN BUSINESS ADMINISTRATION
THE SCHOOL OF BUSINESS, THE UNIVERSITY OF CHICAGO
Vol. XVII, No. 1, 1947

ERRATUM

THIS is being written to correct a serious computational error which was discovered by Mr. Karl Fox of the Bureau of Agricultural Economics, United States Department of Agriculture. The error does not affect the validity of either the methods or the conclusions of the study. The error does greatly affect the numerical magnitudes which will be indicated in the following paragraphs. The author gratefully acknowledges Mr. Fox's help.

For the first paragraph which begins on page 93 and the following paragraphs and figures on pages 93 and 94 read as follows:

The production contour map for feed consumption is shown in Figure 31.^{17a} When the index of animal units was held constant at 80 ($1910-14=100$), the consumption of a marginal unit of feed, when that index was 80, raised the index of livestock production about 36 per cent as much as the increase in the index of feed consumption (Fig. 31). When the index of feed consumption was 120 and that of animal units 80, a marginal increase in feed consumption raised the index of livestock production about 27 per cent as much. The marginal products were, of course, much greater when the index of animal units was held constant at 120. In this case a marginal increase

^{17a} The vertical scale of the figure should be corrected by reference to the following table:

MARGINAL PRODUCTIVITY OF
FEED CONSUMPTION

X_3	X_2		
	80	100	120
	Marginal Product	Marginal Product	Marginal Product
80.....	0.36	0.31	0.27
100.....	.40	.35	.31
120.....	0.44	0.38	0.34

The horizontal scale indicates, of course, changes in X_2 , not X_3 .

in the index of feed consumption from 80 resulted in increasing the index of livestock production 44 per cent as much as the increase in the index of consumption.

The pattern of the marginal products of animal units is, of course, the same as the pattern for feed consumption. The difference in the magnitudes of the marginal products of the two factors of production reflects the difference in magnitude of β and α (Fig. 32 and Table 10).^{17b} If the indexes of both feed consumption and animal units were 100, an increase of 1 per cent in animal units would cause an increase of .55 per cent in the index of livestock production. A simultaneous increase of 1 per cent in the indexes of both productive factors would cause an increase of .85 per cent in the index of livestock production. It must be remembered that the order of magnitudes of the marginal products would change radically if the range of observations were to be substantially extended. The marginal productivity curves increase at an increasing rate as the ratio of the variable to the fixed factors of production decreases. At some ratio, beyond the realm of probability for aggregates such as are here being considered, an increase in the variable factor would undoubtedly result in an increment in the product of much greater proportionate magnitude.

^{17b} Table 10 should read as follows:

TABLE 10
MARGINAL PRODUCTIVITY OF ANIMAL UNITS

INDEX OF ANIMAL UNITS	INDEX OF FEED CONSUMPTION		
	80	100	120
	Marginal Product	Marginal Product	Marginal Product
80.....	0.57	0.51	0.47
100.....	.61	.55	.50
120.....	0.65	0.58	0.54

The vertical scale of Figure 32 should be corrected by reference to Table 10. The horizontal scale indicates changes in X_3 , not X_2 .



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A Supplement to
THE JOURNAL OF BUSINESS OF THE UNIVERSITY OF CHICAGO, April, 1947
STUDIES IN BUSINESS ADMINISTRATION, Vol. XVII, No. 1



The University of Chicago Press • Chicago 37
Agent: Cambridge University Press • London

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ACKNOWLEDGMENTS

THE writer wishes to express his appreciation to the Institute of Meat Packing, the University of Chicago, whose financial assistance made this study possible. He is especially indebted to Professors Edward A. Duddy and George H. Brown for their continuous counsel and co-operation during the development and completion of this work. He is also grateful for the helpful criticisms of Professors G. M. Lewis and T. W. Schultz.

Appreciation is also due to Mr. Burton Wall, whose advice has been of great value in formulating chapter iv, and to Mr. Harry V. Roberts, whose criticisms and mathematical assistance have helped so much.

The arduous task of collecting appropriate data was made easier and its performance more successful by the judgment and help of Mr. Robert J. Eggert

of the American Meat Institute. Acknowledgment is also gratefully made to R. D. Jennings of the Bureau of Agricultural Economics, United States Department of Agriculture; to Mr. Samuel Russell of Swift and Company; to Mr. Kenneth Miller of Armour and Company; and to Mr. Oscar Day of Wilson and Company. These last-mentioned gentlemen co-operated in the early stages of preparation in formulating more clearly the problems involved in the study. Mr. Dean McNeal of the Ralston-Purina Company, St. Louis, Missouri, also co-operated very helpfully in securing data.

Miss Ruth Sternberger performed many of the statistical computations and typed the first draft. Miss Lillian Hunter and Miss Harriet Sadlowska made the charts.

JAMES H. LORIE

CHICAGO, ILLINOIS
December 1946

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INTRODUCTION

IT is the purpose of this study to ascertain the most important immediate and ultimate determinants of annual fluctuations in the production of livestock and livestock products in the United States and to measure statistically the relationship between these determinants and livestock production for the period from 1910 through 1944. This study may prove useful in two ways. First, it is hoped that a methodology will be developed in this macroanalysis that will be useful in facilitating the study of particular problems which confront livestock producers and processors. The last chapter, for instance, develops a form of production function for livestock products which may be used with appropriate data by animal husbandrymen to measure the marginal productivity of feed-stuffs and of animal units and by meat-packers and other processors to estimate the volume of production of particular livestock products. Thus, those in the livestock industry may better be able to allocate economically those factors of production which can be controlled. Second, this study may enable the government, when regulation of the livestock industry is considered necessary, to make the effects of regulation conform more closely to the objectives established by the formulators of social policy.

It was decided to formulate the problem in terms of aggregates rather than in terms of particular segments of the livestock industry. Such a decision necessarily made more severe the difficulties of creating logically consistent and appropriate indexes and also created additional difficulties in interpretation. The

decision was made because the literature, although presenting many studies of hog and beef production or of other livestock enterprises, contains no comprehensive theoretical or statistical work on the whole enterprise of livestock production in this country. This lacuna has prevented the statement of certain generalizations about the interrelationships of the various individual livestock enterprises and about the forces affecting the allocation of resources to livestock production, whatever its form. It is hoped that this study will make and justify some of these generalizations.

The method of analysis which is used was suggested by the works of Professor Paul H. Douglas and his various collaborators in the formulation of production functions for manufacturing and mining.¹ In these works the product, represented by an index of manufacturing and mining, was related as a dependent variable to the factors of production, capital, and labor—the independent variables.² Although the nature of the problem faced by Douglas *et al.* was markedly different in many important respects from the problem of this study, it was found that an organization of the analysis in terms of a product, considered as a dependent variable, and of the primary quantifiable factors of production, considered as independent variables, clari-

¹ C. W. Cobb and P. H. Douglas, "A Theory of Production," *American Economic Review*, Vol. XVIII (March, 1928) (supplement); P. H. Douglas and P. Daly, "The Production Function for Canadian Manufacturers," *Journal of the American Statistical Association*, Vol. XXXIX (June, 1943).

² A more complete discussion will be found in chapter iv.

fied the problem and produced the most useful results. Although many types of factors of production are necessary to produce livestock products, the only factors with yearly fluctuations of an important magnitude are feed consumption and the number of animal units which are fed.³ Consequently, an index of livestock production was related to indexes of these two factors. These factors—feed consumption and animal units—are considered to be at a given time the immediate determinants of livestock production. The second chapter of this study will attempt to ascertain what it is that causes fluctuations in the first of these determinants, feed consumption. The third chapter considers the causes of fluctuations in the second determinant, the number of animal units being fed. The final chapter quantifies the relationship between these determinants and livestock production in the United States during the period 1910-44.

In a study such as this which attempts to measure relationships between aggregates of partially heterogeneous magnitudes, a fundamental problem is that of combining the magnitudes into indexes which accurately represent those characteristics of their component elements which are relevant for the particular problem under consideration. A failure to overcome adequately the necessarily great difficulties involved makes all subsequent work, no matter how keen the insight upon which it is based, of little value. Because of the way in which the production function of the last chapter of the study is constructed and because of the all-inclusiveness of the independent variables, this function can serve, in

a way, as a check on both the accuracy of the data upon which the indexes are based and upon the logical consistency and relevance of the indexes themselves. The first part of this study will describe the basic data and the methods by which the indexes were constructed.

The period covered in the analysis is the thirty-five years from 1910 through 1944. In making the decision as to how far back in time it was desirable to go, it was necessary to consider in the balance the sometimes serious inaccuracies and inadequacies of the data in the earlier years as opposed to the necessity for having enough annual observations to comprise a suitable statistical sample. Most of the series with which this study is concerned are available for all years after 1910. The methods of collecting the data in the earlier years were not so satisfactory as in more recent times; but, in the absence of objective tests of accuracy, it was decided to include these earlier years for the sake of an increased sample.

The decision to extend the study through the war period of extensive governmental regulation was more difficult to make. It was realized that the existence of many governmental controls might result in abnormal reactions and relationships which, when considered together with those of the pre-war years, could obscure the analysis for both the relatively free and the relatively controlled livestock industry. It cannot be denied that the decision to include a period such as 1940-44, in which temporary institutional influences were significant, creates difficulties of interpretation. These difficulties in themselves, of course, are undesirable, but they are counterbalanced by positive and substantial advantages which result from the inclusion of these years. The years after 1940 were ones in which feed sup-

³ The obscuring influence of secular changes of a technological nature in the efficiency with which these factors are used is eliminated by the inclusion of "time" as a third independent variable.

plies, feed consumption, and livestock populations and production reached record levels. Inclusion of this period permitted the range of observations to be markedly increased and provided an illuminating offset to the equally spectacular period of depressed supplies and production which accompanied the drought years of the 1930's. Thus the possibility of a safe extrapolation of the statistical findings was increased.

In regard to such extrapolation a word of caution may be appropriate. Fluctuations in the two primary independent variables can be, and have been at times, significantly affected by governmental action. Through the use of subsidies, loans, and more direct price regulation both the volume of feed consumption and the size of livestock populations can be partially controlled. A governmental policy designed to alter the pattern of the industry as it has existed would, of course, invalidate to a greater or less degree the value of any study based on historical data in forecasting the course of future events. Such a governmental policy could thus destroy a large part of the value of chapters ii and iii of this work. In regard to the last chapter, that which measures quantitatively the relationship between the independent and dependent variables, governmental policy is without influence. So long as scientific knowledge in regard to the breeding and feeding of livestock is acquired, disseminated,

and put into practice slowly and smoothly through time, the relationships established in this fourth chapter will remain valid. The prospects for the continuing validity of this section, dependent as it is upon the evolution of livestock types and upon the education of livestock producers, are probably better than for chapters ii and iii, which can be invalidated in part by the potentially erratic course of governmental policy.

Finally, a word on the statistical methods which are used should be given. Because it has been impossible for any agency to collect data which represent with great accuracy the status of or changes in the operations of the six million farmers with which this study is concerned, refined statistical procedures have in most cases seemed inappropriate. Although statistical processes can never give false information—they reflect only the mechanical and verifiable manipulation of numbers—they can often lead to an unjustified sense of precision and reliability. For the most part the deductions of this work are documented by tabular analyses in the various ways which the succeeding pages will indicate. When recourse is had to multiple linear and curvilinear analysis, it must be remembered that the conclusions are no more valid than the basic data upon which they are based. Caveats in this regard will be given where they seem most needed.

CHAPTER I

THE DATA

SIX basic series are used in the subsequent analyses. They are (1) an index of the supply of feed available for use by crop years; (2) an index of the amount of feed consumed by livestock by calendar years; (3) an index of the carry-over of feed supplies by crop years; (4) an index of the number of animal units on farms each January 1; (5) an index of the number of animal units fed; and (6) an index of the production of livestock and livestock products by calendar years.

THE INDEX OF FEED SUPPLIES

The component parts of this index were combined on the basis of conversion factors representing the relative feed value of the various feeds under average conditions for the United States as a whole. These conversion factors were established by R. D. Jennings of the Bureau of Agricultural Economics of the United States Department of Agriculture and are found in his bulletin, *Feed Consumption by Livestock, 1910-41*.¹ The total digestible nutrients in a feed constitute the common denominator which is frequently used to express relative feeding values. Comparison or combination in terms of total digestion nutrients is useful when the feeds being compared or combined are similar. Such a method would be appropriate for comparing or combining the feed grains or the various types of hay, for instance. Such a method

would not be appropriate in constructing an index of feed supplies which includes such dissimilar feeds as cottonseed meal and cake and wild hay, because the feeding value of the hay would be overstated and that of the meal and cake understated.

The fact that the meal and cake have a relatively high-protein content (protein is necessary for growth and reproduction and is not present in sufficient quantities in most feeds) is not reflected in the relative feeding values as measured by total digestible nutrients alone. Jennings, in recognition of this, has measured relative feeding values in terms of units of digestible protein and of net energy² in the various feeds. Use of the factor "digestible protein" gives weight to the presence of this scarce and necessary feed element. Use of the factor "net energy" gives weight to the calories or therms of energy which feeds make available for growth and maintenance. Since for the purposes of this study it is desirable to weight feeds according to their net contribution to the production of livestock products, Jennings' method seemed appropriate and was adopted.

The feeds included in the index of feed supplies are corn, oats, barley, the grain sorghums, hay, wheat millfeeds, linseed-oil meal and cake, and cottonseed-oil meal and cake. Conspicuous by its absence is pasture, the only major source of feed which has been omitted. Even

¹ R. D. Jennings, *Feed Consumption by Livestock, 1910-41* (United States Department of Agriculture Circular 670 [Washington, D.C., 1943]).

² "Net energy" is a term used to indicate the number of therms in a feed which would, under "normal" conditions, be available for maintenance and growth after digestion is completed.

though pasture furnishes on the average about three-eighths of the feed consumed by livestock in the United States,³ it has been omitted, because feed supplies are significant in this study only in so far as their size affects the allocation of various feeds for different uses. In other words, only those feeds whose supplies consist of allocable stock piles have been considered.

Pasture conditions obviously affect the volume of feed consumption (the index of feed consumption includes pasture), but these conditions do not constitute a basic datum around which future plans of livestock producers are made. Although it is undoubtedly true that changes in pasture make necessary *ad hoc* adjustments of considerable magnitude by livestock men, such conditions can neither be forecast nor planned for and hence have been eliminated from the index of supplies of feed. Even though wide variations in pasture conditions have been experienced, livestock men, in making plans, have no basis for considering that pasture conditions will be other than normal.⁴

Another omission from the index of feed supplies is that great supply of potential feed—wheat. Unlike the feed grains, wheat is sometimes used extensively both as human food and as a livestock feed. In some sections of the country, such as the Pacific Northwest, wheat normally constitutes a significant portion of the concentrates fed to livestock. In the country as a whole, however, excepting the period from 1930 to 1932,

when the Federal Farm Board was liquidating its inventories of wheat, and the years of the second World War, when administered grain and livestock prices made the feeding of wheat a relatively profitable operation, wheat has never constituted in any year since 1910 over 2 per cent of all feed consumed in this country. In 1943, the year of heaviest wheat feeding, wheat was about 4 per cent of all feed consumed. Wheat has not been excluded from the index, however, because of its minor importance (less important sources of feed have been included), but because of the impossibility of defining what constitutes the supply of wheat *as a feed*.

Two alternatives, neither satisfactory, were present. First, all wheat could be considered as part of the feed supply. It is true that all wheat is potentially a feed. Prices in this country, however, have always channeled a preponderant proportion of wheat supplies into flour mills for ultimate use as human food. The inclusion of all this wheat in an index of feed supplies therefore seems unrealistic. It seems probable that such inclusion of all wheat would cause a greater distortion than would its exclusion. As a second alternative it was possible to include in the index of supplies only that amount of wheat which was actually consumed as a feed. This method was rejected because of the necessity of distinguishing between feed supplies and feed consumption. Because a large part of this study is necessarily devoted to a consideration of the relationship between feed supplies and feed consumption, it seemed a logically untenable position to identify as a "supply" only that portion of a commodity which was consumed. Admittedly, the rejection of these two alternatives does not give a completely satisfactory solution to the problem, but the adop-

³ Jennings, *op. cit.*, p. 14.

⁴ In the case of other feeds such as corn, hay, oats, etc., which can be stored, it is possible to make the volume of feed consumption somewhat independent of production during any given year. The extent to which inventories are used to offset the effect of the weather will be discussed in chapter ii.

tion of either alternative seemed to involve greater distortions or logical inconsistencies than did their rejection and the consequent exclusion from the index of a very minor feedstuff.⁵

Also omitted are corn stover and other dry roughage, skim milk, tankage and meat scraps, oat millfeeds, beet pulp, fish meal, and various other by-product feeds. These various feeds constitute in total about 3 or 4 per cent of the entire supply of feed. They have been omitted from the index because of the impossibility of getting reasonably accurate data as to their supply and because such an omission would not significantly impair the usefulness of the index as an indicator of the level of and the changes in the total supply of feed. The scanty evidence which is available indicates that supplies of these omitted feeds fluctuated in the same direction, but with less magnitude, than did those elements of the feed supply included in the index. This evidence, coupled with the minor quantitative significance of these omitted feeds, is the justification for considering the index as constructed in this study representative of the country's allocable supplies of feeds.

Of the feeds in the index corn is by far

⁵ It is thought by some agricultural economists that the reduction in recent years of production costs of wheat would cause a much increased quantity of wheat to be fed to livestock if it were not for governmental programs to support wheat prices. If this thesis is valid, and it seems reasonable, the exclusion of wheat from the index would become of greater importance if such governmental influence were to cease. This study is concerned, however, with historical relationships and not with conjectures as to future governmental policies and their consequences. It is clear that the government can focus sufficient economic power on the agricultural section of the economy to invalidate any conclusions based on historical data.

Wheat is included, of course, in the index of feed consumption. The consequences of the exclusion from one index and the inclusion in another will be discussed in chapter ii.

the most important. It provides about one-fourth of the total feed of the country, including pasture, and constitutes about 50-55 per cent of the index of feed supplies used in this study (Table 1). The supply of corn was computed as of October 1 of each year. The supply figure was obtained by adding the United States Department of Agriculture's figures on corn production to its figures on total stocks of corn on October 1. Before 1926 the Department of Agriculture reported stocks as of November 1. In order to make the supply figures before 1926 comparable with those after 1926, the stocks of November 1 were adjusted on the basis of a three-year overlap in the data (1926-28). It was found that in these three years October 1 stocks were about 1.5 times as great as the November stocks of corn from the old crop. Using this adjustment factor, an October 1 supply figure for the entire period 1910-44 was obtained. These figures, indicating the bushels of corn in this country on the dates indicated, were converted into tons so as to facilitate the use of Jennings' conversion factors.

It was realized that quality as well as quantity should be considered in evaluating the relative feeding value of corn supplies in different years. It has been impossible, however, to improve on the rather imprecise attempts of the Department of Agriculture to take account of qualitative differences. The Department's production series is secured by multiplying estimated acreage by the estimated yield per acre. The voluntary crop reporters who make the estimates of yield attempt to allow for differences in the moisture content of the corn from year to year. In recent years these subjective estimates of moisture content have been supplanted by laboratory analyses. Since moisture content is the

major variable affecting the feeding value of a given quantity of corn, the methods of the Department take into account qualitative differences.⁶ Their production series in an unadjusted form reflects the relative feeding value of different corn supplies in so far as both quantitative and qualitative changes are considered in formulating the series.

Oats, the second most important feed grain, constitute about 5 or 6 per cent of the total feed supplies of this country and about one-eighth of the index in this study (Table 1). The method of determining the supply of oats was the same as that used for corn. Oat supplies, however, were computed as of July 1 instead of October 1. Ideally, of course, the supplies of all the elements of the index would be computed for the same date. This was not possible, however, for the whole period 1910-44 because of inadequate data. It was necessary to decide between making rather large adjustments in the series available in order to secure figures on supplies for the same date or to assume that supplies tended to disappear at about the same rate, figured as a proportion of the total supply, regardless of the size of the supplies. The evidence indicates that this assumption is a valid one,⁷ and therefore, although data on the supplies of the various feeds relate to different dates, these data have been considered suitable to represent the relative amounts of feed available for livestock in the following

calendar year. In other words, it is assumed that, if oat supplies on July 1 of Year A are 125 per cent of supplies on July 1 of Year B, oat supplies on December 31 of Year A will be 125 per cent of supplies on December 31 of Year B. It was felt that errors caused by this assumption would be less than those caused by making large adjustments in the original series of the Department of Agriculture.

TABLE 1
ELEMENTS IN THE INDEX OF FEED SUPPLIES

ELEMENT	WEIGHT IN INDEX	
	1910	1944
Corn.....	55	50
Oats.....	12	11
Barley.....	3	4
Grain sorghums.....	2	3
Total all feed grains.....	72	68
Hay.....	24	26
Cottonseed meal and cake.....	1	2
Linseed meal and cake.....		1
Total oilseed meal and cake.....	1	3
Wheat millfeeds.....	3	3
Grand total.....	100	100

Supplies of barley were computed in the same way as were those of oats and corn. Barley furnishes about 2 per cent of the total feed of the country and constitutes about 4 per cent of the index (Table 1). Supplies of barley were computed as of August 1.

It was necessary to solve some peculiar, though unimportant, problems in computing supplies of grain sorghums. First, it was necessary to estimate the production of grain sorghums for the years from 1910 through 1914 because of the lack of official figures for this period. These estimates were made by use of a

⁶ Many agriculturalists feel that the Division of Agricultural Estimates of the United States Department of Agriculture does not adequately represent the relative feeding value of different corn crops. An attempt is made to reflect these differences, but the range of error can probably be lessened.

⁷ Bureau of Agricultural Economics, United States Department of Agriculture, *Feed Statistics, February 28, 1940* (Washington, D.C., 1940), pp. 17-19, 21-22.

line of relationship between supplies of all feed grains, except the sorghums, and hay and sorghum supplies for the period 1915-41. Because the period 1910-14 was one in which the supplies of feed (except sorghums) were near the central part of the range of observations and because the scatter around the line was slight, it is felt that estimates thus arrived at are reasonably accurate. In any case, the effect of an error on the index would be small because of the slight weight given to sorghums. The second problem arose because of the fact that until 1941 the official figures on sorghum production related to production for all purposes, while after 1941 the production figures are broken down into figures on production for grain, forage, and silage. The figures for 1942-44 were converted on the basis of the line of relationship between production for grain and production for all purposes between 1919 and 1941. Grain sorghums constitute about 1 or 1.5 per cent of all feed supplies and 2 or 3 per cent of the index.

Hay furnishes about one-eighth of all feed in this country and constitutes about one-fourth of the index of feed supplies (Table 1). The problem of evaluating the feeding value of hay supplies was complicated somewhat by the upward secular trend in the quality of hay. This trend in quality has been caused by the widespread substitution of the legume hays such as alfalfa, lespedeza, and red clover for timothy, wild hay, and other grass hays. In 1910, for example, about twelve million tons of alfalfa hay were produced in the United States. This represented about one-sixth of all tame hay production and about one-seventh of the production of all hay.⁸ In 1944 the

United States produced about thirty-two million tons of alfalfa—a production which accounted for about three-eighths of all tame hay and about one-third of all hay produced in this country.⁹ That this shift had some significance in terms of feed value per ton of hay is indicated by a consideration of the relative feeding values of alfalfa and of grass hays, the hays which alfalfa has tended to replace. Under average conditions for the United States as a whole, if the feeding value of a ton of alfalfa be represented by 50, the feeding value of timothy and wild hay per ton will be represented by 40.¹⁰ The alfalfa has 25 per cent greater feeding value per ton. By a weighting of the various hays according to tonnage produced, an average feeding value of 42 for all hay produced in the United States in 1910 was determined. In 1944 the average feeding value was about 47. The average feeding value in the intervening years was determined by use of a straight-line trend from 1910 to 1944. In this way the feeding value of the hay produced for each year was determined for the purpose of allocating to hay its proper weight in the index of all feed supplies.

Cottonseed meal and cake furnished on the average 1 per cent of the feed units consumed by livestock in this country.¹¹ This feed is given a weight of from 1 to 2 in the index (Table 1). The figures on the supplies available on October 1 from 1919 through 1944 were obtained from the Department of Agriculture. For the period from 1910 to 1918 it was necessary to make estimates. This was done by establishing the ratio which existed from

⁸ United States Department of Agriculture, *Hay and Feed Statistics* (Statistical Bull. 11 [Washington, D.C., April, 1925]), pp. 26, 36, 38.

⁹ Bureau of Agricultural Economics, United States Department of Agriculture, *Crops and Markets, January 1945* (Washington, D.C., 1945), pp. 16-17.

¹⁰ Jennings, *op. cit.*, p. 12.

¹¹ *Ibid.*, p. 14.

1919 to 1944 between supplies of meal and cake and the tonnage of cottonseed delivered to mills. Because figures on tonnage delivered to mills go back to 1910, it was possible to derive from this series the estimated supplies of meal and cake. It was found that the tonnage of meal and cake usually amounted to about 40 per cent of the tonnage of cottonseed delivered to mills.

Linseed cake and meal provided less than 1 per cent of the feed units available to livestock and have a weight of 1 in the index. Figures on the supply available on October 1 from 1919 through 1944 are published by the Department of Agriculture. Figures for the period 1910-18 were estimated on the basis of relationship which existed from 1919 to 1944 between the net supply of flaxseed and the supplies of cake and meal on October 1.

Wheat millfeeds furnish about 2 per cent of this country's feed and have a weight of 3 in the index. Supplies of millfeed by months are reported by the Department of Agriculture from 1925 through 1944. The figures for earlier years were estimated on the basis of the fairly constant ratio which exists between the quantity of wheat sold off farms and the supply of wheat millfeeds. The data on millfeeds from 1910-25 were derived from the series on wheat sold off farms.

In summary it may be said that the feeds included in this index constitute between 50 and 55 per cent of all feed supplies in this country. The only significant omission was pasture, which accounts for about 38 per cent of all the feeds and for about 80 per cent of the omitted feeds. The remaining omissions were wheat, a negligible quantity of rye, and various individually and collectively insignificant by-product feeds. The index

as constructed is intended to, and to a large extent does, represent the feeds whose supplies consist of allocable stock piles, weighted according to their feeding values.

THE INDEX OF FEED CONSUMPTION

This index, like that of supplies, was constructed by weighting the various feeds included according to relative feeding value as measured by digestible protein and net energy content.¹² An attempt has been made to include all feeds fed to livestock for which data could be secured. Those feeds in the index are listed in Table 2. The major omissions, of course, are in the roughage group. It has been impossible to get annual data over a long enough period of years to form the basis for reasonably accurate estimates of the consumption of corn fodder, corn stover, kafir stover, oat and wheat straw, cottonseed hulls, etc. Undoubtedly, such omissions have caused the index to fail to reflect some appreciable variations in consumption. These sources of feed become increasingly important in drought periods when the index of consumption probably understates the actual consumption in this country. This bias in the index should be considered, of course, in interpreting those statistical results which depend upon its use.

The index does not include those feeds consumed by horses and mules. Because of the difficulty of measuring the level of or fluctuations in the production of horses and mules, it was decided to eliminate any consideration of either their production or of their feed consumption from the indexes of this study. The index, then, includes all feeds, except certain roughages and by-products

¹² A description and justification for this method of weighting are given on p. 4.

of negligible importance, consumed by all livestock, except horses and mules, in this country.

The following paragraphs will describe the particular problems and specific

TABLE 2
ELEMENTS INCLUDED IN THE INDEX
OF FEED CONSUMPTION

Class of Feed	Individual Feeds
Grains.....	Corn
	Oats
	Barley
	Grain sorghums
	Rye
	Wheat
High-protein feeds....	Gluten meal
	Gluten feed
	Cottonseed meal
	Linseed meal
	Soybean-oil meal
	Soybeans
	Tankage
	Meat scraps
	Fish meal
	Skim milk (dried)
Medium- or low-pro- tein feeds.....	Peanut-oil meal
	Dried brewers' grains
	Wheat bran
	Wheat middlings
	Alfalfa meal
	Hominy feed
	Oat millfeed
	Molasses
	Beet pulp (dried)
	Beet pulp (wet)
Hay and other rough- age.....	Skim milk
	Tame hay (weighted)
	Wild hay
	Pasture

techniques involved in constructing the index. The data on the consumption of corn by calendar years are taken from Jennings.¹³ The figures on corn consumption include the corn in silage. The data on oats come from the same source.

Jennings gives data on the consumption of wheat, rye, barley, grain,

sorghums, and other grains under the single head "Other Grains." In order to determine the feeding value of the tonnage reported under this heading, it was necessary to break the aggregate down into its component parts because of the significantly different feeding value of, say, wheat and rye. The breakdown was achieved by subtracting from the aggregate "Other Grains" the Department of Agriculture's figures on the consumption of wheat and of rye. The residual represented primarily the consumption of barley and the various grain sorghums. In so far as the feeding values of these latter feeds are virtually the same,¹⁴ no further breakdown was needed. The negligible consumption as feed of buckwheat and rice has not been considered. Thus, it was possible to determine the tonnage fed of wheat, rye, barley, and the sorghums. Using Jennings' factors, these figures on tons consumed were converted into figures on feed units consumed. Those figures which related to the various grains other than corn and oats were recombined into the series "Other Grains."

The data on the consumption of hay also come from Jennings.¹⁵ The figures given by him relate to all hay, with no breakdown into wild hay and the various varieties of tame hay. In order to achieve this breakdown, it was assumed that the consumption of the various hays in any calendar year was in proportion to their production in the preceding year. Figures on production, by kinds, are published by the Department of Agriculture. By this method it was possible to determine the feed units represented by Jennings' figures on the consumption of all hay.

¹⁴ The conversion factors are the following: barley, 94; sorghums, 95.

¹⁵ *Op. cit.*, p. 3. The data for 1942-44 come from a personal letter to the author.

¹³ *Op. cit.*, p. 3. The data for 1942-44 are from a personal letter from Jennings to the author.

It was found that in the early years of the period a ton of hay had a feeding value equal to 42 or 43 per cent of that of a ton of corn. In the last years of the period hay had a feeding value about 47 per cent that of an equal weight of corn.

A more difficult problem was presented in the attempt to determine the feeding value of the Jennings' category "Other Concentrates." Included under this heading were the oilseed meals and cakes, the by-product feeds of plant origin, and the by-product feeds of animal origin. Jennings reports the aggregate tonnage of these feeds consumed annually by the various classes of livestock.¹⁶ He also reports, for the years 1929-33 and 1938-40, the consumption by all livestock of the individual concentrates, stated both in tons and as a proportion of the total tonnage of "Other Concentrates" consumed. In order to make use of this information in determining the number of feed units of "Other Concentrates" consumed in each year, it was necessary to make certain assumptions. It was necessary to assume that, for any class of livestock, each feed (under "Other Concentrates") that commonly appears in the ration is in the same proportion to the total ration of "Other Concentrates" for that class of livestock that said feed is to the amount of these feeds (i.e., those feeds which appear in the ration of said class of livestock) fed to all livestock in the years 1929-33 and 1938-40. The meaning of the preceding cumbersome sentence can be expressed by the following formula

$$\frac{a}{b} = \frac{d}{c},$$

where

a = the total quantity of any given feed commonly found in ration of a particular class of livestock

b = total ration of "Other Concentrates" of particular class of livestock

c = total amount of "Other Concentrates" of kinds included in b fed to all livestock

d = total quantity of feed of type a fed to all livestock

It was assumed further that the average proportions which existed in the years 1929-33 and 1938-40 existed for all other years from 1910 to 1944. These assumptions obviously do some violence to the facts, but they seemed necessary in view of the need for finding some method of appraising the feeding value of these feeds which constitute about 5 per cent of total feed consumption.

To make the method clear, the following paragraph will indicate the specific procedures involved in computing the feed units of "Other Concentrates" consumed by cattle other than dairy cows. The concentrates other than grains, found in significant quantities in the rations of these cattle were cottonseed meal, linseed meal, soybean-oil meal, oat millfeeds, molasses, dried beet pulp, wet beet pulp, and others.¹⁷ The total tonnage of these feeds consumed by all livestock, on the average, for the years 1929-33 and 1938-40 was 3.8 million tons. Of this total, cottonseed meal constituted 51 per cent, linseed meal 8 per cent, soybean-oil meal 14 per cent, oat millfeed 4 per cent, molasses 3 per cent, dried beet pulp 7 per cent, wet beet pulp 5 per cent, and other concentrates 8 per cent. Using these percentages as weights, and using Jennings' factors which represented the relative feeding values of these feeds when fed to cattle, it was possible to determine the factor appropriate for converting the figures on the tonnage of these feeds consumed by beef cattle into figures on feed units consumed. The fac-

¹⁷ Includes wheat, bran, wheat middlings, hominy feed, etc.

¹⁶ *Ibid*, pp. 22, 24, 25, 27, 29.

tor which resulted from the use of this method was 223.¹⁸ Jennings' figures on the tonnage of "Other Concentrates" consumed by cattle other than dairy cattle were multiplied by 223 to obtain the number of feed units consumed.

In a similar manner the consumption by other classes of livestock was calculated. The consumption by all livestock was secured by adding the consumption by the various classes of livestock, thus calculated.

There remains only the problem of computing the consumption of pasture. This is necessarily a task which does not permit precise results. The index of the production of pasture used is that prepared by Malcolm Clough, formerly of the Bureau of Agricultural Economics of the United States Department of Agriculture. Clough describes the construction of the index as follows:

The index numbers of feed value of pastures and ranges from 1909-43 are based on estimated acreage of plowable pasture, woodland, and pasture other than plowable and woodland, adjusted for changes in condition in pastures and ranges from year to year. The census data available indicate that plowable pasture acreage fluctuates inversely with acreage of land in principal field crops. Based on this relationship plowable pasture acreage was estimated for intercensal years from 1909-43. Acreage in woodland pasture and other than plowable pasture does not fluctuate greatly from year to year. Acreages of these two groups are averages for the census years 1924, 1929, and 1934. These are taken as typical of the area in pasture other than plowable for the entire period. These are weighted to the equivalent of plowable pasture acreage on the basis of the estimated livestock carrying capacity of the three types of pasture. Thus woodland pasture is given a weight of .45 as compared with 1.0 for plowable pasture, and pasture other than plowable and woodland is given a weight of .25.¹⁹

¹⁸ Corn is considered to be equal to 100.

¹⁹ Malcolm Clough, "Feed Production in the United States: Index Numbers, 1909-43" (un-

Clough obtains the total acreage in pasture, in plowable pasture equivalent, by the method indicated above. This acreage is then multiplied by the figure representing average pasture and range conditions for the months from May through October.²⁰ The figure resulting from this multiplication represents the production of pasture. It has been assumed in this study that the changes in the consumption of pasture have been proportional to the changes in production as represented by Clough's index.

The index of all feed consumption was constructed by combining the pasture index with the index for all other feeds. The pasture index was given a weight of 0.37; that of all other feeds, a weight of 0.63. These weights were determined on the basis of Jennings' figures on feed consumption for the years 1929-33 and 1938-40. In the earlier period pasture represented 36.8 per cent of all feed consumption; in the latter period, 37.8 per cent.²¹ The consumption of feeds by horses and mules was subtracted from the total consumption by all classes of livestock before the final formulation of the index.

THE INDEX OF CARRY-OVER OF FEED SUPPLIES

This index was constructed for the purpose of indicating fluctuations in the carry-over, or stocks, of feed supplies. Each owner of feedstuffs must make the decision as to the desirability of using, selling, or storing his feeds. The possibility of increasing or depleting stocks creates a competition between present and

published manuscript, Bureau of Agricultural Economics, United States Department of Agriculture).

²⁰ May through August for the years 1910-14.

²¹ Jennings, *op. cit.*, p. 14.

future consumption of feeds, and this competition, in so far as it affects the consumption in any year (it cannot affect the consumption secularly), affects livestock production in any year. Because feedstuffs are partially interchangeable, because some feedstuffs deteriorate rapidly, and because some feeds are not stored for other reasons in significant quantities, it has not been necessary to include in the index of stocks all of those feeds in the index of supplies and the index of consumption. Corn and oats have been included because their stocks are by far the most important of the feed grains quantitatively and because changes in their stocks are representative of changes in the stocks of those grains that have been omitted.²² The stocks of these grains constitute normally about 90 per cent of the stocks of all feed grains carried over from one crop year to the next. Hay has been included as being by far the most important roughage which is carried over from year to year.

Although the statistical evidence is slight, what evidence there is indicates that the carry-over of roughages other than hay is negligible. Likewise, the carry-over of the various by-product feeds is slight.²³ These feeds are for the most part purchased to meet current feeding requirements. They are seldom purchased for inventory speculation—that is, to meet needs which will arise in any subsequent production period. Stocks of grain are carried by the farmer in many cases because selling grain is often for the farmer a commercial operation of primary importance which he attempts to time so as to produce a profit. The purchase of by-product feeds, on the other hand, represents a significant, but

not a major, cost of production which is usually incurred regardless of fluctuations in prices. Nor is the carry-over by industrial producers large. The impossibility of precisely hedging inventories deters the risky accumulation of large inventories by businesses for whom the sale of by-product feeds represents a minor source of revenue. Therefore, in so far as carry-over of corn, oats, and hay constitutes a large proportion of the carry-over of all feeds from one crop year to the next, and in so far as the size of the carry-over of corn, oats, and hay is affected by much the same forces that affect the size of the carry-over of the omitted feeds, the inclusion of these feeds (corn, oats, hay) in an index of stocks should insure that index's being representative of the stocks of all types of feed.

The term "stocks" means, for the purposes of this study, those supplies of feed in storage at the time of the harvest of the new crop of feed—the supplies in storage being from the preceding crop. Stocks of corn are computed as of October 1. Figures on these stocks are from the Department of Agriculture. Previous to 1926 the Department reported stocks as of November 1. These figures were adjusted to make them comparable to the series after 1926 on the basis of the three-year overlap in the series from 1926 through 1928. Stocks of oats were computed as of July 1. Before 1926 the Department of Agriculture reported stocks as of August 1. These figures were adjusted to make them comparable to the post-1926 series on the basis of the 1926-28 overlap. As in the case of corn, the conversion factor was determined by finding the average ratio of the stocks for the different months in the three years for which figures on stocks for both months were available. Stocks of hay were computed as of May 1, the data

²² Primarily barley.

²³ The by-product feeds include the oilseed meals and cakes, tankage, millfeeds, etc.

coming from the Department of Agriculture.

THE INDEX OF ANIMAL
UNITS ON FARMS

In constructing this index, too, the basic problem was that of finding the appropriate method of combining different series into a single index on the basis of some factor common to all series. The method chosen was that of weighting the various classes of livestock according to

TABLE 3*

RELATIVE CONSUMPTION OF ALL
FEED BY THE VARIOUS CLASSES
OF LIVESTOCK UNDER AVERAGE
CONDITIONS IN THE UNITED
STATES, 1910-44

Class of Livestock	Factors Indicating Relative Consumption of All Feed
Milk cows	1.000
All horses and mules	0.950
Other cattle	0.700
Hogs	0.300
All sheep and lambs	0.125
Turkeys	0.076
Chickens†	0.019

* Source: Jennings, *op. cit.*, p. 52.

† Allows for both laying flocks and chickens raised.

their relative consumption of feed. The relative weights established by Jennings were used.²⁴ These weights indicate the relative consumption of all feed per animal by the various classes of livestock under average conditions for the United States as a whole, assuming a "normal" production of livestock products by the various classes of animals. The factors for the various types of animals are given in Table 3.

In order to determine the number of animal units on farms for any year, these factors were multiplied by the figures representing the number of the corresponding classes of livestock on farms

January 1, and the products of these multiplications were summed. The assumption of a normal production of livestock products per animal for each class of livestock is, of course, somewhat at variance with the facts. Nevertheless, such an assumption was necessary in order to make possible a differentiation between the index of the number of animal units on farms and the index of production of livestock products. If the weights for the former index had been varied each year in accordance with changes in production, this index would have assumed an identity with the index of livestock production. By the maintenance of constant weights, changes in the index could arise from changes in the only remaining relevant variable, the numbers of the various classes of livestock on farms. The data on these numbers are published by the Department of Agriculture.

In this index, too, horses and mules were not considered. For the purposes of the analyses which are undertaken it was necessary to maintain consistency between the various indexes. Because horses and mules were not included in the index of feed consumption, and could not be included in the index of livestock production, these animals have been excluded from the index of animal units. This index has been extended back to 1867 for reasons explained in subsequent sections of this study.

THE INDEX OF ANIMAL UNITS FED

Although the index of animal units on farms is suitable to represent the number of animal units at discrete points of time, it is not suitable to represent the number of animal units that are fed during any year, because many animals are born and slaughtered in less than a twelve-month period. Fluctuations in

²⁴ *Op. cit.*, p. 52.

poultry numbers and especially in the hog population within any twelve-month period are particularly important in creating the need for this additional index. The index of animal units on farms will be used in the analysis of causes for fluctuations in animal populations, because the data can be extended back to 1867, a necessary extension if the measurement of cycles and trends is to be made. The index of animal units fed is used in the last chapter of the study, where it is necessary to consider feed consumption and animal units fed as the determinants of livestock production. This index of animal units fed was constructed in the following manner:

1. The number of cattle, both dairy and "other," which were fed is represented by the number on farms on January 1.

2. The number of poultry fed is represented by the number of hens and pullets (chickens and turkeys) on farms on January 1 plus the number of chickens and turkeys raised during the subsequent twelve months.

3. The number of sheep fed is represented by the number on farms on January 1.

4. The number of hogs fed is computed by adding together one-half of the preceding spring pig crop, all of the fall pig crop, and one-half of the following spring pig crop.

5. The resultant numbers for the various classes of livestock were multiplied by the corresponding conversion factors representing the relative percentages of all feed consumed, and the results of the several multiplications were summed.²⁵

The data for these various computations were secured from unpublished compilations in the Bureau of Agricultural Economics. Complete data are available back to 1920 only. The series was extended to 1910 on the basis of the close relationship which existed from 1920 to 1944 between the series representing animal units on farms and that representing animal units fed.

²⁵ It will be noticed that horses and mules are omitted from this index, too.

THE INDEX OF THE PRODUCTION OF LIVESTOCK AND LIVESTOCK PRODUCTS

This index has been constructed to represent the production by calendar years of livestock and livestock products. The production of livestock is distinguished from the production of livestock products in that the former refers to increases in the weight of live animals on farms, while the latter refers to the production of eggs, milk, and milk derivatives and, in addition, to beef, pork, lard, lamb, mutton, and other products of livestock slaughter.

Data on the production of eggs and of dairy products are published by the Department of Agriculture, the production of the various dairy products being stated in terms of milk equivalents of a given butterfat content. The data on the production from meat animals are also reported by the Department. Because the term "production" is somewhat ambiguous in this context, the meaning of the Department's data needs some explanation.

Farm production of livestock and livestock products from meat animals is computed for each state, the production for the United States being the sum of the production in the individual states. In order to determine the production in each state, the following steps are taken:

1. The inventory of each class²⁶ of livestock at the beginning of the year is determined. The inventory is measured in pounds and not in numbers of animals.
2. To the figure obtained in the first step are added the following:
 - a) Out-shippments of each class of livestock stated in pounds.²⁷

²⁶ Cattle and calves, sheep and lambs, and hogs.

²⁷ Data based on reports of state of origin of receipts by stockyards companies, packers, and on state sanitary boards and railroad data. In states where such data are incomplete, the Department relied

- b) Local slaughter, stated in pounds.²⁸
 - c) Farm slaughter, stated in pounds.²⁹
 - d) Any increases in inventories of the various classes of livestock which may have occurred during the year, stated in pounds.
3. From the figure resulting from the operations in the second step the following subtractions are made:
- a) In-shipments of each class of livestock, stated in pounds.³⁰
 - b) Any decreases in inventories of the various classes of livestock which may have occurred during the year, stated in pounds.

In all cases the production of meat was stated in pounds converted to a live-weight equivalent. Although the consideration of exports and imports is not explicit in the above explanation, the method of dealing with in-shipments and out-shipments necessarily involves the inclusion of exports in, and the exclusion of imports from, the final production figures.

The various types of meat and of poultry and dairy products are combined on the basis of conversion factors representing the relative amounts of feed units required to produce a unit of the various products. The factors, taken from Jennings, are given in Table 4. Jennings'

on sample data and on census reports. Weights per head are estimated on the basis of the weights of livestock received at the principal markets.

²⁸ Includes retail slaughter and commercial wholesale slaughter when this is on a small scale and unimportant in the aggregate.

²⁹ Estimated slaughter on farms for home use and for the sale of meat.

³⁰ Based on records of inspections by the Bureau of Animal Industry and by the state sanitary boards and on railroad data.

method of determining the relative number of feed units of all feed required to produce a unit of the various kinds of livestock and livestock products was to divide the total number of feed units fed to each class of livestock by the total production of livestock and livestock products coming from that class of livestock.

TABLE 4*

FACTORS REPRESENTING RELATIVE AMOUNTS OF ALL FEED REQUIRED TO PRODUCE THE SPECIFIED LIVESTOCK PRODUCTS UNDER AVERAGE CONDITIONS IN THE UNITED STATES

Product	Unit	Factor
Hogs	Pound, liveweight	4.65
Beef cattle	Pound, liveweight	13.75
Sheep and lambs	Pound, liveweight	15.25
Chickens	Pound, liveweight	5.54
Turkeys	Pound, liveweight	5.18
Milk	Pound	1.11
Eggs	Egg	0.67

* Source: Jennings, *op. cit.*, p. 44.

The data on the annual production of the various classes of livestock and livestock products came from Jennings.³¹ In order to establish a more reliable trend line for this series, it was extended back to 1897 on the basis of work done for the National Bureau of Economic Research.³² For the years since 1942, the data have been taken from *Agricultural Statistics, 1944*, and from other publications of the Department of Agriculture.

³¹ Jennings, *op. cit.*, pp. 15-16.

³² H. Barger and H. H. Landsberg, *American Agriculture, 1899-1939: A Study of Output, Employment and Productivity* (New York: National Bureau of Economic Research, 1942).

CHAPTER II

A CONSIDERATION OF THE NATURE AND CAUSES OF FLUCTUATIONS IN FEED CONSUMPTION

AS INDICATED in the Introduction, an attempt will be made in this chapter to explain the nature and causes of fluctuations in feed consumption. It will be impossible within the scope of this study to define quantitatively all the cost, supply, and demand functions which determine the allocation of resources to the production of feeds or which determine the temporal, spatial, or use allocation of feedstuffs themselves. It will be impossible, for instance, to isolate and quantify the influence of those economic factors which affect the use of feeds in one time period as against another; it will be impossible to measure exactly the factors determining the direction and volume of the foreign trade in feeds between the United States and other countries; and it will be impossible to define precisely those forces which channel feeds into agricultural and non-agricultural uses. It is hoped, however, that the discussion will evolve some simplifying generalizations around which such statistical-economic studies can usefully be organized, and it is intended that historical data will be used to indicate the relative importance of these subsidiary problems to the solution of the all-embracing problem: "What determines the annual volume of feed consumption?"

THE ALLOCATION OF GIVEN FEED SUPPLIES

As a first step in the deductive inquiry, the short-run relationship between feed supplies and feed consumption will

be considered. That is, within a single crop production period, will feed consumption necessarily or typically be greater than, equal to, or less than the production plus carry-over of feed in this country? Further, if the relationship varies among these three possibilities from year to year, what factors are most important in determining the particular relation during a particular period?

Obviously, an upper limit to feed consumption within the United States is set by the size of supplies available to the United States. The term "available" cannot have a helpful meaning if it is thought that the availability is determined solely by physico-technical difficulties in transportation and storage. Under modern conditions almost all the feedstuffs of the world¹ could be transported with small deterioration to the United States within a calendar year if costs were not considered. Clearly, however, these costs are considered, and the term "available" must imply an economic availability. That is, a supply of feed is considered to be available when its price, representing a cost of production, is such that the use of the feed would yield a greater net monetary return to the purchaser than would result if the purchase of the feed were foregone. The price which is considered by potential purchasers in the United States in deciding whether or not to purchase feed, domestic or foreign, is the delivered price. Under almost all conditions the

¹ Excluding pasture, of course.

delivered price of foreign feedstuffs is such that its use by American farmers is unprofitable. In other words, under "normal" conditions the feeds which are economically available for use in this country are limited to those feeds which are produced here. The term "normal" refers to periods in which exogenous factors do not create conditions which make the importation of feedstuffs profitable. The particular exogenous factors which have existed during the period 1910-44 are the severe drought of the mid-thirties and the regulated price structure of World War II. In these periods only have there been appreciable net imports of feeds into the United States. The economic conditions which these factors created and their implications for American farmers deserve explanation.

A large percentage of the total costs of farming are, under normal conditions, fixed costs. Figures to substantiate this assertion are unfortunately not available for the entire period being studied, but the evidence that is available, for the years 1929 and 1939-44, is convincing. In an elaborate study the Bureau of Agricultural Economics does provide national aggregates of agricultural production costs for the seven years referred to.² Although the Bureau's categorization does not correspond precisely to the conventional economic division between variable and fixed costs, it is possible to derive some useful information from its study. Excluding such costs as labor, feed, purchased livestock, fertilizers, motor-vehicle operating costs, and a miscellaneous category of current costs exceeding in magnitude all labor costs,

the Bureau lists as noncurrent (or fixed) costs the following: maintenance or depreciation of buildings and equipment, realty taxes, and mortgage interest payments. To these "fixed" costs an economist must add interest on invested capital. A crude but conservative estimate of the magnitude of this cost was obtained by multiplying the value of all farm real estate in the years 1929 and 1939-44 by 0.03 and subtracting from the resulting products the mortgage interest payments for the corresponding years. Adding this interest cost to the other fixed costs, total fixed costs were found to constitute the following percentages of total costs in the indicated years:

1929.....	43	1942.....	32
1939.....	43	1943.....	30
1940.....	40	1944.....	31
1941.....	34		

In considering whether these years are representative of the entire thirty-five-year period, no definite conclusions can be drawn. It does seem probable, however, that variable costs such as labor, feed, fertilizer, etc., would be relatively less important quantitatively in periods of less intense economic activity and lower prices and that fixed costs would consequently be a larger percentage of total costs in such periods. The appearance of a downward trend in this percentage during the war years 1939-44 seems to support this thesis. A more important, necessary, and less equivocal adjustment in these cost figures would result if the cost of maintaining breeding herds be considered a fixed cost for dairy-men and beef producers. Such a consideration is not unreasonable when it is realized that these herds represent necessary, and not easily replaceable, instru-

² Bureau of Agricultural Economics, United States Department of Agriculture, *Income Parity for Agriculture*, Part VI, Sec. 1 (Washington, D.C., October, 1945).

ments of production of the farmers' vendable commodities, milk and beef.³

A still more important adjustment to these figures representing "fixed" costs seems justified when it is realized that labor can be considered to be for most agricultural entrepreneurs a "fixed" cost. The cost of the labor of the farmowner and of his family, frequently a large one, varies only slightly, if at all, with variations in the output of the farm. When these adjustments have been made, it is probable that the fixed costs of farmers are substantially over 50 per cent of total costs. In any case, the proportion of total costs that are fixed in agricultural enterprises is "large" in comparison with most industrial firms. That is, the value of a breeding or dairy herd is just as great after periods in which feeding has been abundant enough to produce offspring or milk in marketable quantities as after periods in which feeding has been just abundant enough to maintain life.

The significance of this relatively high ratio of fixed to total costs, when stated in terms of neoclassical economic diagrams, is that the minimum point of the curve of average total costs is relatively far from the origin along the axis representing output. The rational producer, if he produces at all, will produce at least as much as is necessary to make his average total costs a minimum.⁴ Although it is

³ Another way of seeing why such costs might reasonably be considered to be fixed is to consider the magnitude of the "user" costs of these herds for the farmer. (Following J. M. Keynes, "user costs" are defined as follows: user cost = $[E_0 - M] - E_1$, where E_0 is the value of original facilities at the beginning of the production period; M is cost of maintenance and depreciation if the facilities were not used; and E_1 is the value of the original facilities at the end of the production period.) These "user" costs are zero under most conditions of commercial production.

⁴ This assumes the perfect competition which is approximated in the agricultural economy.

quite certain that the farmer does not think in these terms, it is probable at least that the issues are sufficiently clear to insure the farmer's choosing to produce above a certain minimum level, in the short run, almost regardless of the cost of feed. As to the possibility of not producing at all, the lack of opportunities in the short run for alternative gainful employment brings into play the unmeasurable influences of habit, tradition, and the conventional American reverence for industriousness—influences which make it probable that the farmer will produce rather than rest even though objective economic facts indicate the lack of profitability of production.

Another and perhaps more compelling factor affecting the decision to produce or not to produce is the need for meeting certain cash obligations, such as taxes and mortgage interest payments. This need may coerce the farmer to produce in order to secure cash, even though the decision results in a greater loss, in the conventional economic sense, than would a decision not to produce.

All the foregoing involved and theoretical discussion has been for the purpose of stating those economic generalizations which indicate the reasons why, under normal conditions, an upper limit on feed consumption is set by the amount of feed that is in this country, and why, under conditions of severe drought, importation of feeds is economically justifiable. As for the other exogenous influence, the regulated price structure of World War II, the economic implications are apparent. The ceiling prices on grains in this country and in Canada, coupled with the subsidies for finished beef and the government-supported prices for all livestock, created an almost riskless economic environment for the raising and feeding of livestock. With this

environment substantial quantities of wheat, oats, and barley were imported from Canada for use as livestock feed during the years 1942-44. This was the only period, other than the drought years of the thirties, in the thirty-five years from 1910 through 1944 in which there were net importations of grains for use as feed.⁵

Having established the fact that under most conditions feed is not imported, it remains to inquire how supplies in this country are allocated for different uses. It is commonly recognized that the primary factor regulating the volume of the consumption of feed by the various classes of livestock are the various feed-livestock and feed-livestock-product-price ratios. For instance, the hog-corn ratio is a very useful and much-observed guide as to the profitability of feeding corn to hogs. When this ratio has been relatively high, farmers typically react as though it were relatively profitable to raise relatively more hogs and to feed them for relatively longer periods. Con-

versely, when this ratio has been low, the feeding of hogs may not be considered to be profitable and corn may be diverted to other uses. Similar observations on the significance of the beef-corn, egg-feed, milk-feed, and other ratios are valid. Each of these ratios acts as a regulator of the amount of feed used in the production of the various livestock products. Deductions as to the effect of changes in these individual ratios are easily made, and empirical evidence as to the soundness of such deductions is not lacking. The questions as to the necessary relationship between these different ratios and as to the significance of this relationship in regard to the consumption of feed by all classes of livestock have not been so frequently considered and are not so easily answered. In the subsequent paragraphs an attempt will be made to determine deductively the answers to these questions.

If it is possible to demonstrate that there is a necessary relationship between the prices of all feedstuffs and the prices of all livestock products, it may be possible to make the necessary deductions concerning the interrelationships among the different feed-livestock product ratios. By showing that the prices of feedstuffs in almost all cases adjust themselves to the prices of livestock products, so that in any crop year the amount fed to livestock will very nearly equal the amount of feed produced in this country in the preceding year,⁶ it will be possible to make clear the nature of the interrelationships of these feed-livestock price ratios.⁷ If such a demonstration is pos-

⁵ Admittedly, the problem of spatial allocation of feedstuffs at the national level has not been solved by the preceding discussion of foreign trade. Even if it had been desired to solve the problem more exactly, however, it would have been impossible to do so. The comment of Dr. Alonzo E. Taylor on the foreign trade in corn seems relevant. He says: "All in all, the plus-and-minus error in the corn crop estimate may well be over 100 million bushels, a figure which bulks large against the corn crop passing to terminal markets and especially against the amount passing to export" (*Corn and Hog Surplus of the Corn Belt* [Stanford, Calif.: Stanford University Press, 1932], p. 48). Such considerations led Henry Schultz, for example, to exclude any consideration of exports from a study whose prime purpose it was to measure statistically and precisely the demand function for corn. The omission of exports and/or imports is not of importance for Schultz's statistical study, as he demonstrates (*The Theory and Measurement of Demand* [Chicago: University of Chicago Press, 1938], p. 240), and a fortiori the omission is of small consequence in this inquiry. For the same reasons, quantification of the forces affecting foreign trade in other feedstuffs seems both impossible and unimportant.

⁶ Less a small and almost constant amount of feeds which are used in industry and for human food.

⁷ The sentence to which this footnote is appended is an oversimplification but a useful one. When untidy facts fail to fit this thesis, the nature and importance of the incompatibility will be indicated.

sible, it will be possible to answer the stated questions without the necessity of analyzing the factors which influence the prices of livestock products themselves.

Consideration will now be given to the simplest relevant case, the determination in the short run of the price of pasture. The short run in this context refers to any calendar year. By considering only the price in any year, the problem has been reduced to that of determining price over the production period for the commodity. By considering pasture, the complications involved when it is possible to

tially produced by the use of pasture is made easy. Because of the assumed lack of alternative uses and the assumed fixed supply, the price of pasture is determined by the prices of the products for which it is a factor of production. Figure 1 illustrates the relationship.

The price of pasture cannot exceed the value of its marginal product, necessarily a livestock product, if the pasture is to be used. Because pasture cannot be used for anything other than livestock production, the price of pasture must not exceed the value of its marginal livestock prod-

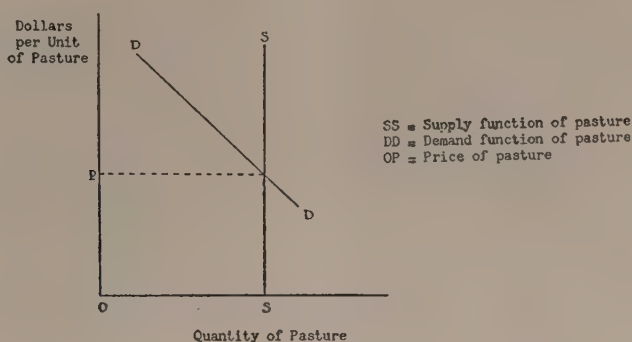


FIG. 1

store the commodity or to import it into or export it from the economy being considered are avoided. And, for the moment, let it be assumed that the supply over the production period is fixed. That is, let it be assumed that, once acreage has been allotted to its various uses, the amount of pasture available to livestock can neither be increased by more intensive fertilization nor decreased by the use of grass or other pasture crops as green manures. In view of these assumptions and of the very important fact that the possibility of using pasture and ranges for anything other than livestock feed is negligible, an understanding of the relationship between the price of pasture and of livestock products which are par-

uct if it is to be used at all. Because it has been assumed that the supply is fixed and that pasture cannot be carried over from one production period to another, a rational owner of pasture would sell (or rent) his pasture resources for use in livestock production, whatever the price, rather than have his resources unused and yielding no return. In this case it is clear that the price of pasture must adjust itself, in this sense, to the price of livestock products. In conventional economic terminology, pasture can be said to be price-determined rather than price-determining. The use of the term "price-determined" may lead to misinterpretations. It does *not* mean that the price of livestock products uniquely determines

the price of pasture. The marginal productivity of the pasture is also a determinant of its price. In so far as the supply of pasture affects its marginal productivity, though not its marginal productivity function, the *supply* of pasture can be considered to be a determinant of its price. In other words, since pasture will rent for the value of its marginal product, both its marginal productivity and the price of its product determine the price of pasture.⁸

Now, let some of the assumptions in regard to the complete inelasticity of the short-run supply curve of pasture be relaxed. It is possible to increase the amount of pasture available to livestock, when prices offer sufficient stimulus, by the use of suitable fertilizers. Such increases in the intensity of cultivation have occurred during the years of World War II when high livestock prices have been associated with a much increased use of lime, phosphate, and other fertilizers. Such a practice would make necessary a modification of Figure 1 whereby the supply curve at its upper reaches would deviate from the vertical by curving away from the y-axis. It is also probable that the lower limits of the supply curve should curve toward the y-axis. The amount of pasture available to livestock may in any year be less than the amount that is produced if pasture is plowed under, in the interest of increased future yield, rather than grazed. The decision as to the allocation of pasture for these two competing uses depends, of course, upon present and anticipated fu-

ture price ratios. The possibility of defining this supply curve statistically with any precision is even less than that of solving the economic problems involved in the foreign trade in feedstuffs. As was stated in chapter i of this study, the acreage devoted to pasture can be determined only by considering it as a residual—a residual which fluctuates inversely with the acreage devoted to other crops. There are no reasonably accurate figures available on the acreage which is plowed under, nor are there accurate figures on the *increases in pasture yield attributable to changes in the rate of fertilization within a single production period*. It is impossible even to appraise with knowledge the importance of this, at present, insoluble problem. Pasture constitutes about 37 per cent of the country's feed supply. Excepting the probably slight deviations from the vertical in the short-run supply curve of pasture, the consumption of pasture in any production period will equal the production of pasture in that period.

The case of hay is similar to that of pasture. The bulkiness of hay in relation to its value precludes the possibility of there being a significant amount of foreign trade in hay. Hay, like pasture, can be used in appreciable quantities for nothing but livestock feed. It differs from pasture in that it is possible to carry hay over from one production period to the next. Because of this, it is also possible to deplete the inventory which existed at the start of the production period. How does this complication affect the relationship between hay prices and the prices of those livestock products for which it is a factor of production? The possibility of storage really means that in any calendar year the amount available for use can exceed as well as be less than the amount that is produced. In the case

⁸ The theory of price determination of pasture and range must be modified slightly because of the existence of range areas which are administered by the federal government under the Taylor Grazing Act. These administered prices, too, however, are varied with the prices of the animals which are using the area involved. This note is appended for the sake of completeness rather than for its practical significance.

of pasture, supply was equal to production which approximately equaled consumption. In the case of hay, supply differs from production by the amount of the carry-over, and production differs from consumption by the amount of any depletion from or addition to this carry-over or inventory.

The inventory itself is used normally as a sort of operating reserve. As in any continuing business operation, it is often economically wise to attempt to prevent the stoppage of all operations because of the unexpected shortage of a factor of production whose supply cannot be increased, regardless of need or effort. Therefore, hay stocks at the end of the production period usually constitute about 25 per cent of the average annual production. It is possible both to add to and to subtract from what shall be called this "normal" inventory. The decision as to the advisability of changing this inventory is based on the relationship between present and anticipated future prices. If it is felt that the future price of hay will be sufficiently greater than the present price to more than pay for all the costs of storage, some of the current production of hay will be added to the normal inventory instead of being used or sold.⁹ If, on the other hand, it is felt that future prices will be greater than present prices by less than this amount, it is probable that some depletion of the normal inventory will take place. The act of increasing or of depleting the normal inventory in itself sets up forces which

tend to limit the amount of the increase or the depletion.

If it is anticipated that the future prices will be great enough to make storage an economic operation, the act of storage will tend to raise the present and depress the anticipated future price. Conversely, a depletion of inventory will operate so as to depress present and to increase anticipated future prices. Therefore, changes in the normal inventory are automatically self-limiting. The average change in the inventory of hay during the thirty-five years from 1910 through 1944 was about 4 per cent of production and about 16 per cent of the average inventory. This potential variation in the amount of hay that will be available for consumption during any production period can be indicated diagrammatically. Because the fluctuations in supply around current production are caused by variations in the ratio of present to anticipated future prices rather than by changes in the present price alone, it may be considered appropriate to indicate the potential variation in the amount of hay that will be available for consumption by a series of vertical lines rather than by the conventional positively sloped supply curve. Figure 2 illustrates indirectly the relationship between the price of hay and the price of livestock products.

If it is assumed that the demand for the hay has unitary elasticity, the variations in the price of hay caused by these increases or depletions in inventories would be approximately 4 per cent above or below that price which would have existed in the absence of a change in inventory. If the elasticity were greater than 1, the changes in price would be less than 4 per cent; if the elasticity were less than 1, price would vary by more than 4 per cent. In any case, the price of hay adjusts itself to the price of livestock prod-

⁹ Consumption by producers has the same economic significance as consumption by nonproducers. Therefore, the demand by producers will be considered as a part of aggregate demand rather than as a deduction from supply. Sale or use by producers will be considered to have the same economic significance in reference to this analysis (cf. F. H. Knight, *The Ethics of Competition* [New York and London: Harper & Bros., 1936], p. 190).

ucts so that its consumption by livestock in any year differs from its production in the same production period by a relatively small amount. Hay will be purchased so long as its price does not exceed the value of its marginal product. The major changes in price are caused by changes in the demand curve. Changes in this curve are caused only by changes in the price of livestock products. As has been shown, consumption of hay very nearly equals the production of hay in any production period. Therefore, it is safe to say that the price of hay adjusts itself to the price

dustrially, corn is used to produce starches and dextrines, alcohol, corn oil, etc. As human food corn is consumed as such, as corn meal, and in the form of manufactured breakfast foods. Some corn is also used each year for seed. Although the variety in the possible use for corn is great, the aggregate consumption for these various purposes is small. Complete data on the consumption of corn for food, seed, and industry are available only since 1926. In the period from 1926 through 1944 consumption in any year for all these purposes never exceeded 290

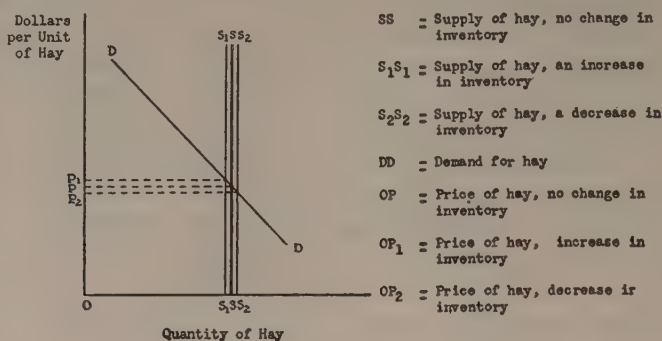


FIG. 2

of livestock products in such a way that it is profitable to feed all (or slightly less or slightly more than all) the hay that is produced in any such period. Hay furnishes about 15 per cent of the total feed supply. The consumption of this major constituent of the feed supply in any year very closely approximates production during that year.

Next, the relationship between the price of corn and the price of livestock products during the production period will be considered. An additional complication is introduced because of the fact that corn is a raw material in industrial processes, is used as human food, and can be exported and imported.¹⁰ In-

¹⁰ A consideration of the effects of the existence of foreign trade in corn will be postponed.

million bushels. The maximum consumption, therefore, constituted about 10 per cent of the normal annual production of corn. A striking aspect of the data is the apparent relatively complete inelasticity of the demand for corn for these purposes.

Although it is impossible to make precise observations as to the nature of the demand for corn during this period of drought and war, it is easy to see that very great fluctuations in price were associated with only slight fluctuations in the quantity used for these purposes. Considering 1909-14 to equal 100, the average of the monthly prices of corn in 1933 was 57. In 1934 the drought caused the index to rise to 95. This increase of over 60 per cent in price was accompanied by a de-

cline in consumption for food, industry, and seed of less than 4 per cent. From 1937 to 1938 the price index declined from 148 to 76, a fall of almost 50 per cent. During this period consumption of corn for food, industry, and seed rose from 192 to 199 million bushels, a rise of less than 4 per cent.

Other evidences that changes in the price of corn have little effect on consumption of corn for these purposes is found by a mere visual examination of Table 5. A priori reasoning would lead one to expect statistical evidence of inelasticity, imprecise as it is, such as is found in this table.¹¹ Changes in the price of corn have a very minor effect on the total costs of those industrial products for which corn is a raw material; they influence to an almost completely negligible degree the profitability of using corn as seed. If we consider this demand for corn to be completely inelastic, the effect of this demand on the relationships between the supply of corn and demand for corn during any production period is shown diagrammatically in Figure 3. This figure differs from that for hay because of the consideration of the demand for uses other than for livestock feed. In Figure 3 this demand has been represented as being completely inelastic. The evidence indicates that this assumption is probably not unrealistic. If some degree of elasticity were present, the effect on the price of corn and on the consumption of corn by livestock would be slight. As with hay, the possibility of depleting or increasing normal inventories is represented by the vertical supply curves S_1S and S_2 . If there were not uses for corn other than for livestock feed, the price of corn would be OP , OP_1 , or OP_2 , depend-

ing on whether there were no changes in the existing inventory during the production period, additions to inventory, or depletions of inventory. Because of the demand for the food, industrial uses, and seed, the price of corn is either OP_1 , OP_1 , or OP_2 , depending on the presence or absence of changes in inventory. The pres-

TABLE 5*
ANNUAL CONSUMPTION OF CORN FOR FOOD,
INDUSTRY, AND SEED, AND THE PRICE OF
CORN IN THE UNITED STATES, 1926-44

Year	Consumption of Corn for Spec- ified Purposes (Millions of Bushels)	Index of Price of Corn (1910-14=100)
1926.....	199	109
1927.....	208	123
1928.....	214	139
1929.....	201	136
1930.....	177	121
1931.....	174	78
1932.....	182	44
1933.....	187	57
1934.....	180	95
1935.....	216	121
1936.....	200	119
1937.....	192	148
1938.....	199	76
1939.....	208	74
1940.....	230	92
1941.....	285	100
1942.....	289	124
1943.....	239	160
1944.....	270	175

* Source: Bureau of Agricultural Economics, United States Department of Agriculture.

ence of this inelastic demand for corn means that the consumption of corn by livestock during any production period must be less by a constant amount than it would be in the absence of such a demand. This has the same effect as moving the SS curve to the left a constant amount.

The possibility of changes in inventory creates possible deviations of consumption by livestock from production-less-a-constant. Because changes in inventory create forces that tend to coun-

¹¹ Even allowing in an intuitive way for the effect of variables which are not considered, there seems to be evidence of great inelasticity.

teract and limit the changes, the variations in price that can be caused by inventory fluctuations are in theory (and in reality) relatively small. The major changes in price must be caused by shifts in the demand curve representing the demand for corn for use as livestock feed. As in the case of hay, if we assume the marginal physical productivity of corn to remain constant, the variations in this demand curve can come only from variations in the price of livestock products.¹² Thus, neglecting for the moment foreign trade in corn, the price of corn is deter-

ment is determined by the magnitude of the price differentials between this and other countries. When these differentials exceed all transportation and selling costs and all intervening tariffs, corn will be shipped.¹³ Such shipments are automatically self-limiting because of their effect on the price differentials. Thus, although there is evidence that these shipments respond immediately to price fluctuations, the volume of the movement is normally quite small.

In only five years since 1910 has the net movement exceeded 2 per cent of the

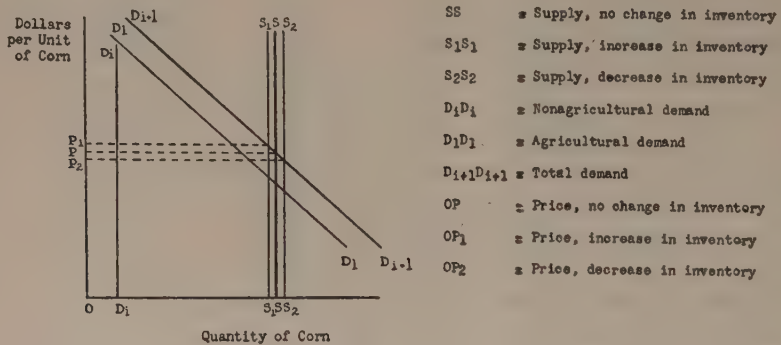


FIG. 3

mined primarily by the price of livestock products. The price of corn adjusts itself to the price of livestock products so that in any production period the consumption of corn will closely approximate the production of corn less the almost constant amount used for food, industrial products, and seed.

The above relationship is altered somewhat by the existence of foreign trade in corn. Corn is relatively valuable for its bulk, relative to hay at least, and is normally shipped both to and from this country. The magnitude of the move-

production in the preceding year. In these five years the sensitiveness of movements of corn into and from the country to abnormally large price fluctuations can be seen. Two of the five years were 1920 and 1921.¹⁴ Following the precipitous price deflation of 1920-21, exports increased in 1920 to 3.7 and in 1921 to 5.7 per cent of the production in the corresponding years. The other three years of abnormally large foreign movements of corn were in the mid-thirties. In 1934 the drought sent the

¹³ The existence of quotas, special trading agreements, and other sorts of trading regulations would make necessary a qualification of this statement.

¹⁴ The years referred to are crop years beginning October 1.

¹² This is based on the familiar economic principle that the price of a factor of production will be equal to the value of its marginal product at the equilibrium point and under perfect competition.

price of corn up over 60 per cent. As a consequence of this, the normal net outward movement of corn was reversed and 36 million bushels of corn were imported—an amount equal to 2.5 per cent of the production in 1934. The second onslaught of the drought in 1936 caused a further sharp increase in corn prices and another heavy importation of corn. In the crop year 1936-37 over 100 million bushels of corn were imported—over 6 per cent of the production in 1936. From 1937 to 1938 the index of the price of corn dropped almost 50 per cent, caus-

ing in the price of our corn will increase the outward movement or will lessen an inward movement, and a rise in the price of corn will have an opposite effect.

As has been shown, the supply of corn available in this country for use during a production period, in the absence of foreign trade, is represented by a series of vertical lines. If the imports are considered an addition to the supply and exports a decrease in supply, the effect of foreign trade on the preceding diagram (Fig. 3) is illustrated in Figure 4. When the price of livestock products is

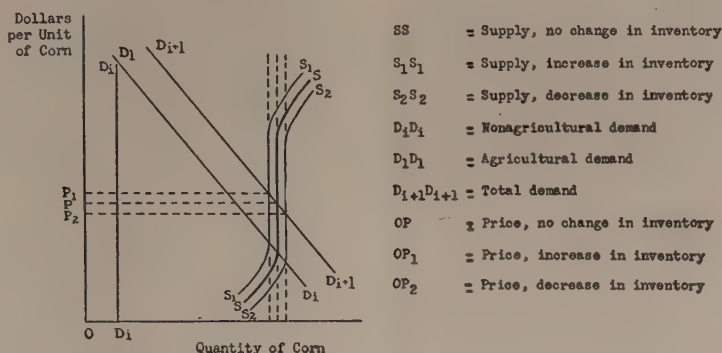


FIG. 4

ing the inward movement to be transformed into a net outward movement of 138 million bushels. Although such observations of unadjusted data cannot indicate with certainty the nature of the line of relationship between prices and foreign movement, what evidence there is seems to indicate that changes in the price of corn are associated with relatively large changes in the foreign movement of corn, *ceteris paribus*. The nature of this relationship need not be defined precisely, however, for our purposes. The data and a priori reasoning indicate that the direction and magnitude of the flow of corn are determined by price differentials between this and other countries. Other things remaining constant, a fall

such that the aggregate demand curve for corn (D_{i+L}) would cause the price of corn to effect the importation of corn, the supply curve moves to the right and prevents the price from being as high as it would have been in the absence of such importation. Conversely, when the demand curve for corn is such that exports of corn are encouraged, these exports—represented by the shift to the left of the supply curve—prevent the price from being as low as it would have been in the absence of such exports. These price influences cannot be quantitatively defined in the absence of statistically determined demand and supply curves. It is probable that the effects of foreign trade on the price of corn are appreciable, but in

almost all years the small volume of this trade precludes the possibility that such price effects are of major importance.

Figure 4 illustrates the nature of the various influences on the price of corn. Although the demand for corn for food, seed, and industry, the possibilities of increasing or depleting inventories, and the existence of a foreign trade in corn all influence its price, the statistical evidence available seems to indicate that the aggregate effect of these factors is small compared to the effect of the demand by domestic livestock producers. The minor influences can cause the consumption of corn to differ from production in any production period, but the amount of this variation will theoretically be small.¹⁵ Professor Schultz went so far as to say in this connection: "We decided also to neglect net exports and to consider corn demand (consumption) for any year as being approximately measured by the total production for the same year, feeling that the neglect of both carry-over and net exports will not materially affect the major findings of this investigation."¹⁶ Corn represents normally about one-fourth of our feed supply, while hay, pasture, and corn represent about three-fourths. The theoretical and statistical evidence indicates that for this portion of our feed supply consumption must closely approximate production within the production period.

Of the other sources of feed, little additional need be said. The price of oats is determined in much the same way as that of corn. The grain sorghums, on the other hand, are more like hay in that there are no uses for these grains other than for feed. The various by-product

feeds, too, are price-determined rather than price-determining because of the absence of uses alternative to the feeding of livestock. All the preceding reasoning has been for the purpose of showing that the consumption of all feed by livestock in this country during a production period must be nearly equal to the production during the preceding period. This conclusion carries with it the corollary that for any given level of feed supplies and livestock inventories some sort of reciprocal relationship between changes in the various feed-livestock price ratios must exist. That is, any diminution in the beef-corn ratio with a consequent diminution in the quantity of corn going to beef cattle will, under most circumstances, be accompanied by an increase in the hog-corn ratio of some other livestock-corn price ratio, with an accompanying increase in the quantity of corn going to the class of livestock affected. Such a reciprocal relationship must exist, if, as has been theoretically demonstrated, feed production and consumption are to equal or to approximate each other during the production period.

In the preceding pages an attempt has been made to discuss the spatial, temporal, and use allocation of feedstuffs during a production period of one year. It was seen that the foreign trade between this and other countries in feedstuffs has been of small importance. Although no attempt was made to measure with precision the effect of changing cost-price ratios on the volume of this trade, the authority of Schultz was used to document the assertion that such a measurement was impossible with existing data and that the lack of such a measurement was of negligible consequence in any study such as this. More attention has been given to the temporal allocation of feeds, although in this area, too, an

¹⁵ The possibility of a more complete statistical documentation of this statement is slight (see Taylor, *op. cit.*, p. 48).

¹⁶ *Op. cit.*, p. 240.

exact quantification of storage schedules is both impossible and of negligible importance.¹⁷ In regard to the allocation of feedstuffs to nonagricultural uses, there is a greater possibility for fruitful inductive research. Such research is, however, beyond the scope of this study. It is enough merely to give some theoretical and inductive evidence of the nature of this industrial and human demand for feeds. The evidence indicates that this demand is very inelastic. Because this is so, it is possible to consider this demand as being a constant subtraction from the amount of feed that is available to livestock, and the problem simplifies into one of determining the forces affecting only temporal and spatial allocation. It is recognized that the assumption of inelasticity has not been rigorously documented and that further work is indicated.

Now, in view of the above considerations, it seems justifiable to assert that, for the elements of the feed supply which have been considered,¹⁸ feed consumption will approximate in any production period the production of feed in the preceding period. This statement is open to the charge that it is the "degree of approximation" rather than the "fact of approximation" that is of interest. To this charge there is at present only one answer—namely, that, for the elements of the feed supply so far considered, consumption differs from production by an unmeasurable and unimportant amount. This is true even if the insignificant changes in stocks be added to the insignificant amounts of feed entering foreign trade and to changes in industrial and human consumption. It is true that

changes in feed supplies tend to affect uses of feed for these purposes in the same way and that, therefore, the effects of such changes are cumulative rather than offsetting. Even so, the assertion that the aggregate is relatively unimportant seems justified.¹⁹ The narrowing of this small range of unexplained variation is a worthy goal for further research.²⁰

THEORETICAL CONSIDERATION OF CAUSES OF ANNUAL FLUCTUATIONS IN FEED CONSUMPTION

The preceding discussion has concerned, of course, price relationships during a single production period—a period in which the quantity of feed available to livestock was fixed except for the minor changes which could be effected through fluctuations in inventories and through foreign trade. It is now pertinent to ask how these relationships differ when one considers a period of time long enough to permit changes of greater magnitude in the quantity of feed that is available. Such variations come from changes in the production of the various feeds, and these latter changes are of two sorts. First are those changes attribut-

¹⁹ These uses have never absorbed as much as 5 per cent of the feed supply in any year from 1910 to 1944.

²⁰ No extended discussion of variations in the amount of wheat that goes to livestock seems justified. The determination of the demand function for wheat as a livestock feed would be a difficult (perhaps impossible) and time-consuming task. Tentative efforts toward indicating the effect of important variables on the quantity of wheat fed (e.g., Geoffrey Shepherd, *The Coordination of Wheat and Corn Price Controls* [Iowa State College, Agricultural Experiment Station Research Bull. 330 (Ames, Iowa, June, 1944)]) are of little help. It is enough for the purposes of this study to know that wheat has never constituted over 4 per cent of all feed consumed in this country, even if the unprecedented rate of feeding during World War II be included. Yearly fluctuations in wheat feeding have been, of course, of much smaller magnitude.

¹⁷ Schultz, *op. cit.*, pp. 239-40. Schultz's arguments apply to corn and, it is believed, with even greater certainty to hay, pasture, and other feeds.

¹⁸ The most important omission is wheat.

able to the conscious plans of farmers regarding acreage allocations and intensity of cultivation. Second are those changes beyond human control which are attributable to weather-caused fluctuations in yield per acre.

In regard to the first class of changes, it is apparent that the farmer is severely limited in his decisions as to the allocation of acreage among different uses by the paucity of alternatives which are available economically. Unquestionably very nearly 100 per cent of all land now devoted to agriculture cannot be diverted to nonagricultural uses with any increase in the productivity of the resources so employed. The territorial expansion of urban centers does achieve an infinitesimal diversion of resources, as does the increasing activity in petroleum operations and in mining. On the other hand, there is no evidence that much land has, in the last three decades, been brought into agricultural use for the first time. Upward trends in the acreage of the grain sorghums, soybeans, flax, etc., have been offset in part at least by downward trends in acreage devoted to corn and to plowable pasture. It is clear, of course, that land and other resources are drawn into and excluded from agricultural production with variations in price-cost ratios. It is beyond the scope of this study to do more than indicate that such shifts in land resource allocation have been small in the period from 1910 to 1944 and that in this area further investigation is indicated. In view of the historically small shifts in acreages from and into agricultural use (in the period 1910-44), the allocation of land by farmers among different uses resolves itself, therefore, almost exclusively into the problem of shifting land from one sort of agricultural use to another.

Again, it is clear that the farmer's de-

cision must be confined within fairly narrow limits. Little of the range land of this country can be shifted to other uses, even considering the potential irrigability of some areas. Over the period 1910-44 the average yearly percentage fluctuation in the acreage allocated to ranges and pastures in this country was about 1.15 per cent.²¹ During 1918 and 1919, when the high price of wheat caused relatively large acreages of land in the Great Plains area to be shifted from range to wheat, the percentage change in the acreage allocated to range and pasture in this country decreased only 3 per cent. Thus, although it is undoubtedly true that considerable acreages in this area can be shifted between feed production and food production, the changes in any year have historically always been only a small percentage of the total acreage devoted to range and pasture.

The long-term trend in the acreage devoted to this low-intensity usage of land is slightly downward. From 1910 to 1944 the decrease was at the rate of 0.04 per cent per year. Recent campaigns by the various state experiment stations and by the Department of Agriculture to induce farmers to substitute pasture for intertilled crops—principally corn—have slowed this trend somewhat. However, since most of the land taken from intensive cultivation was land devoted to corn,²² the effect on the total feed supply has been slight. Land used for growing corn is typically subjected to a rotation which includes oats, hay (alfalfa), and sometimes wheat. Permanent pasture in

²¹ Malcolm Clough, "Feed Production in the United States: Index Numbers, 1909-43" (unpublished manuscript, Bureau of Agricultural Economics, United States Department of Agriculture), p. 20.

²² This program for soil conservation has had its greatest results in Missouri, Iowa, and other states of the Corn Belt.

Iowa, and presumably in most of the Corn Belt, is considered to have a feeding value per acre about equal to an acre of oats and to about one-third of an acre of corn or alfalfa.²³ Since wheat is used in this area in most years almost exclusively for food, the switch from intensive cultivation to pasture increases the feed supply in so far as this phase of the rotation is concerned. In general, it seems safe to say that the diversion of land in the Corn Belt from corn and the other crops conventionally found in the rotation to pasture has not significantly affected the feed supply. Probably the only significant potential cause of acreage allocation's having a major influence on the feed supply lies in the possibility of developing an industrial crop which can be raised successfully under the climatic conditions existing in the Corn Belt.²⁴

Although changes in acreage have been small, changes in the yields of pastures and ranges have been of considerable significance. In the thirty-five years 1910-44 the average yearly percentage fluctuation in yield (or condition) was 8.4. The extreme yearly fluctuations were of much greater magnitude. The yield (or condition) in 1935 was 42 per cent greater than in 1934. For the decade of the 1930's the average yearly fluctuation was over 14 per cent. This contrasts with an average yearly fluctuation in acreage of less than 2 per cent during the same period. These figures are given merely to provide statistical confirmation to the generally known principle that annual fluctuations in the feed derived from range and pasture are caused predominantly by weather-induced fluctuations

in yields rather than by planned changes in acreage.

In regard to the amount of feed derived from corn the situation is much the same, the major proportion of yearly fluctuations being attributable to fluctuating yields rather than to fluctuations in the acreage allocated to corn. In spite of well-financed governmental programs designed to reduce the acreage in this country devoted to the growing of corn, the corn acreage in 1944 was only about 1 per cent less than the 1910-44 average. The average annual percentage fluctuation in corn acreage over the thirty-five-year period was only about 3 per cent. It is reasonable to expect that corn acreage would fluctuate within narrow limits. The requirements of good (economic) agronomy and good (economic) farm management make it, in most cases, unwise for farmers to adjust acreages of field crops on the basis of short-term price changes. Such an adjustment, to be at all successful, would involve a reasonably accurate prediction of future prices and the abandonment of a long-term land-use program based on agronomic principles of soil conservation.

It is needless to emphasize here the hazards involved in attempting to forecast price changes as much as a year in advance—especially when unpredictable weather is such an important factor in determining prices—or to point out the failure of relatively sophisticated economists and statisticians consistently to forecast agricultural prices with accuracy in the absence of the necessary basic data regarding future weather conditions. It is true that farmers do adjust the acreage allocated to certain food crops—for example, potatoes and cabbage—on the basis of anticipated future prices, but the lack of close substitutability of these products makes their price

²³ R. Schickele, *Economics of Agricultural Land Use Adjustments* (Iowa State College of Agriculture and Mechanic Arts, Research Bull. 209 [Ames, Iowa, March, 1937]), p. 355.

²⁴ Soybeans are an example of such a crop.

fluctuations somewhat independent of one another and makes such adjustments in acreage feasible, if we grant reasonably accurate predictions.²⁵ In regard to the major field crops, including all the primary feedstuffs but pasture, however, the close substitutability of one feed for another makes the various fluctuations tend to be the same in direction and not widely different in magnitude. It would be romantically optimistic, indeed, if farmers violated a planned agronomic program in the hope that successful prediction of the small changes in the relatively stable differentials in the prices of the various crops suitable for planting could be achieved.

The statistical evidence tends to confirm the statement that farmers do not juggle the acreages of the feed crops with which this study is concerned on the basis of short-term price changes.²⁶

Hay, like corn, shows very much greater fluctuations in yield than in acreage harvested, the average annual percentage fluctuations in yield being almost 10 per

cent, while the fluctuations in acreage were less than 3 per cent. The same pattern is true for the other feed crops: barley, oats, the grain sorghums, etc.

In this section an attempt has been made to provide a theoretical explanation of the fact that changes in production from one production period to another have been primarily due to weather-induced fluctuations in yield rather than to the plans of farmers. Empirical investigations to support this theory are not lacking.²⁷

CONSIDERATION OF THE INDEXES OF FEED SUPPLIES, CARRY-OVER, AND CONSUMPTION

Before going on to consider the relationship between feed consumption and livestock production, it might be well to consider, first, as well as the imprecision of the data permits, the actual relationship between feed supplies and feed consumption as it has existed in this country between 1910 and 1944. In the theoretical discussion it was pointed out that feed consumption would fluctuate differently than feed supplies to the extent that stocks were increased or depleted and exports or imports took place.²⁸ In the following paragraphs the relevant indexes will be studied in order to determine in a rough way the various interrelationships among them.

²⁵ Such predictions are usually in substantial error, if widely fluctuating acreages are evidence.

²⁶ A study by Harry Pelle Hartkemeier seems particularly pertinent here. Hartkemeier tried to determine the supply function of potatoes and of corn. His conclusions can be indicated in summary form by the following quotation: "The reaction of the production of potatoes to the money price of the preceding year, time, and July temperature of the current and preceding years was established, the determining factors being named in the order of their importance. . . . The production of corn reacted to the July temperature of the current year, but the reaction to the money price of the preceding year and to time could not be accepted as significant on the basis of the data available" (*The Supply Function for Agricultural Commodities: A Study of the Effect of Price and Weather on the Production of Potatoes and Corn* ["University of Missouri Studies," Vol. VII, No. 4 (Columbia, Mo., October, 1932)], p. 60). Hartkemeier used both correlation and path-coefficient analysis and concluded that the relationship between the production of corn and the price of the preceding year can be represented only by a horizontal line.

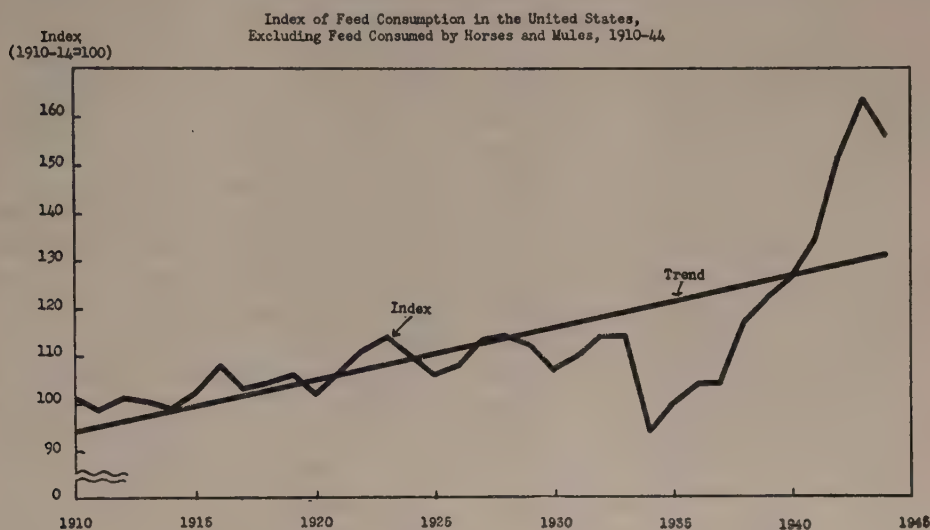
²⁷ G. F. Warren and F. A. Pearson, *Interrelationships of Supply and Price* (Cornell University Agricultural Experiment Station Bull. 466 [Ithaca, N.Y., March, 1928]), pp. 102-3; E. G. Misner, "Studies of the Relation of Weather to the Production and Price of Farm Products. I. Corn" (unpublished manuscript, Cornell University), pp. 55, 82, 92-102, 104-5; C. W. Crickman, *Feed Grains and Meat Animals in War and Peace* (Washington, D.C.: Bureau of Agricultural Economics, United States Department of Agriculture, November, 1945), p. 6; Hartkemeier, *op. cit.*

²⁸ This neglects nonagricultural uses of feed and fluctuations in the quantity of wheat fed.

First, however, it seems desirable to examine the nature and magnitude of the fluctuations in the index of feed consumption. If the level of feed consumption during the period 1910-14 is considered to equal 100, the index rose from 101 in 1910 to 156 in 1944. The low point was in 1934, when the index dropped to 94; the high point, in 1943, when the index reached 164. A straight line fitted

more occurred in eight of the years. The drought and World War II were the events which caused these relatively violent yearly changes.

Although some information about the relationships among supplies, consumption, and storage might be gained from a statistical study of the earlier period (1910-33), it is doubtful that the data upon which these series are based are of



The trend was upward at a rate of 1.08 per cent per year. The droughts of the mid-thirties and the unusual conditions of wartime caused large deviations below and above the trend line.

FIG. 5

by the method of least squares for the thirty-five-year period has a slope of 1.08; that is, the index increased at an average rate of slightly over 1 per cent a year. From 1910 to 1933 the annual fluctuations were, in one sense, quite uniform. The fluctuations were small, being in all cases less than 6 per cent per year and less than 5 per cent in eighteen of the twenty-four years (Fig. 5). After 1933 the character of the fluctuations changed markedly. Fluctuations of more than ten points occurred in three of the eleven years, while fluctuations of five points or

such a high degree of accuracy as to permit valid conclusions to be reached. As was indicated earlier,²⁹ the errors in the estimates of corn production, one of the most reliable series, probably amount to as much as 100 million bushels—over 3 per cent of the average production. Errors in the estimates of other components of the indexes are at least as great. Schultz omitted any consideration of carry-overs of corn, for instance, because changes in stocks on farms were so small “when compared with the admittedly

²⁹ See p. 20.

large errors in the underlying production series."³⁰ Although it is felt that such an omission is unnecessary, it is probably true that little significance can be attached to fluctuations in the index of less than 5 per cent. The indexes during this earlier period of small fluctuations are helpful because they indicate that only relatively small fluctuations occurred (and, by contrast, that subsequent fluctuations were relatively great), because they provide a basis for constructing trend lines over a satisfactorily long period, and because they furnish an opportunity to see whether fluctuations in feed consumption are of a magnitude comparable to that in the series which are thought to be related. In regard to this last point, the fact that these fluctuations are small is of significance even though their exact magnitude probably is not. In the period 1934-44, however, the fluctuations were of such great magnitude that, even though the data be imprecise, the indexes reflect with adequate accuracy the changes that actually occurred. With these thoughts in mind, it is possible to proceed to an examination of the data to see whether the deductions of earlier pages are confirmed in fact.

The most important deduction made was that feed consumption in any year must closely approximate the production of feed in the preceding production period. In view of the insignificance of changes in carry-over, supplies can be used instead of production in this relationship. This substitution has certain advantages which will become clear. This relationship can be seen statistically in two ways. First, the two series can be plotted together as indexes with a common base period. When this is done, it is seen that yearly changes in the two series

tend to be in the same direction (Fig. 6). Because index numbers are used and because the feed consumption was smaller quantitatively than were supplies in the base period, the upward trend in both series tends to create a divergence in the level of the two series in the later years. The effect of this difference in bases can be eliminated by considering only the changes in each series from the preceding year. When this is done, the close relationship between the series becomes more apparent (Fig. 7). Changes were in the same direction in over three-fourths of the years. In only seven years was the change in one series accompanied by a change in the opposite direction in the other series. In three of these six years the changes were less than 5 per cent and can probably be disregarded. The only year in which supplies changed by more than 6 per cent and consumption changed in the opposite direction was 1931 (Fig. 7). Feed consumption in that year remained about unchanged in the face of a decline in supplies of 12 per cent. An explanation can be found in the operations of the Federal Farm Board—operations which accounted for a very great increase in the amount of wheat fed to livestock. Wheat, not considered primarily as a feed and not included in the index of supplies, was fed to livestock in 1931 at a rate about three times normal. The increase over the average for the preceding ten years was over 100 million bushels—an increase which accounted for the stability of the index of feed consumption. In the absence of the Farm Board's attempt to deplete its swollen wheat inventories, the index of feed consumption would have declined as did the index of feed supplies.

It is evident at once that in the pre-war (World War II) years the fluctuations in consumption, though in the same

³⁰ *Op. cit.*, pp. 240-41.

direction as fluctuations in supplies, were of smaller amplitude than the fluctuations in supplies (Fig. 7). In these pre-war years stocks of grain and hay on farms acted as a shock-absorber to lessen the impact of changing supplies on the

changing supplies, though the changes in stocks did not constitute a large proportion of total supplies (Fig. 8). An increase in feed supplies of 10 per cent over the preceding year was accompanied, on the average, by an increase in



¹ At beginning of crop year before the year indicated.

² For the year indicated. Pasture is omitted.

The direction of change was the same in over 80 per cent of the years.

FIG. 6

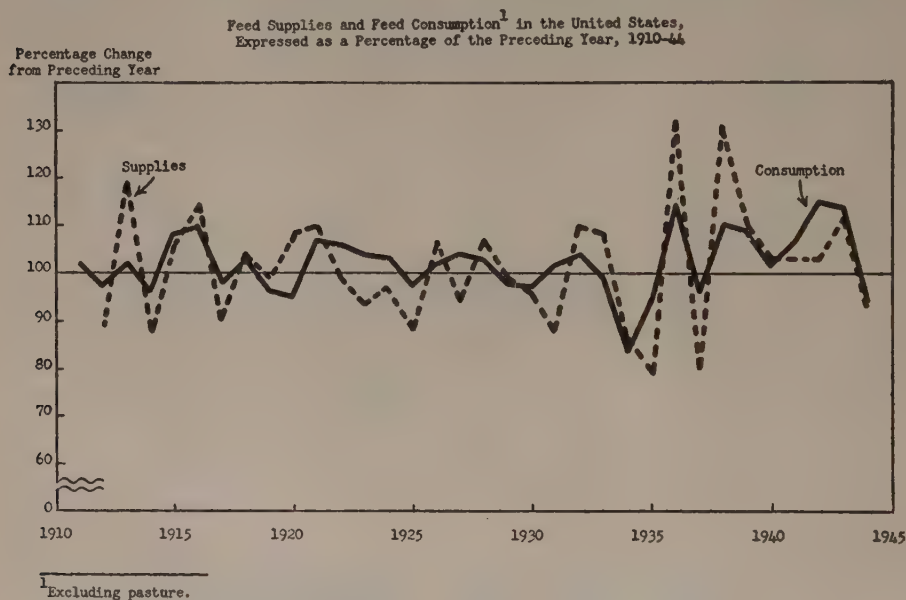
livestock production operations of farmers. Stocks were depleted in the years following harvests that were smaller than normal and were expanded somewhat after unusually good harvests. The line of relationship between yearly changes in feed supplies and in stocks of feed grains and hay on farms one year later indicates that stocks showed large percentage fluctuations in response to

stocks one year later of almost 50 per cent. Similarly, a decrease of 10 per cent in supplies was accompanied, on the average, by a decrease in stocks one year later of about 30 per cent.

During the early forties this tendency of farm inventories of feed grains and hay to change in the same direction as supplies was reversed, and stocks were depleted under the urgency of wartime de-

mands for meat, in spite of successive bumper crops. The change in stocks never exceeded 3 per cent of supplies and for most years was of considerably smaller magnitude. The effect of this use of stocks is seen in the difference between the average yearly percentage fluctuation in feed supplies and in feed consumption. The former series had an average annual fluctuation of 9.9 per cent, while the lat-

plies and in stocks does not render invalid the theory that feed consumption will approximate feed production in the preceding production period, it is now possible to add that consumption typically has been slightly less than production when this production has been "large" and that consumption typically has been slightly greater than production when production has been "small." The



The close correlation between the series is more evident after the elimination of trend.

FIG. 7

ter had an average fluctuation of 4.3 per cent.

Although the basic inaccuracy of the data on stocks probably makes exact quantitative estimates, such as have been made, of doubtful value, it does seem justifiable to state that stocks are typically used to negate the impact of changes in supplies on the scale of livestock operations. This tendency is persistent and of appreciable importance. Its existence makes possible a qualification of the original deduction. Although this relationship between changes in sup-

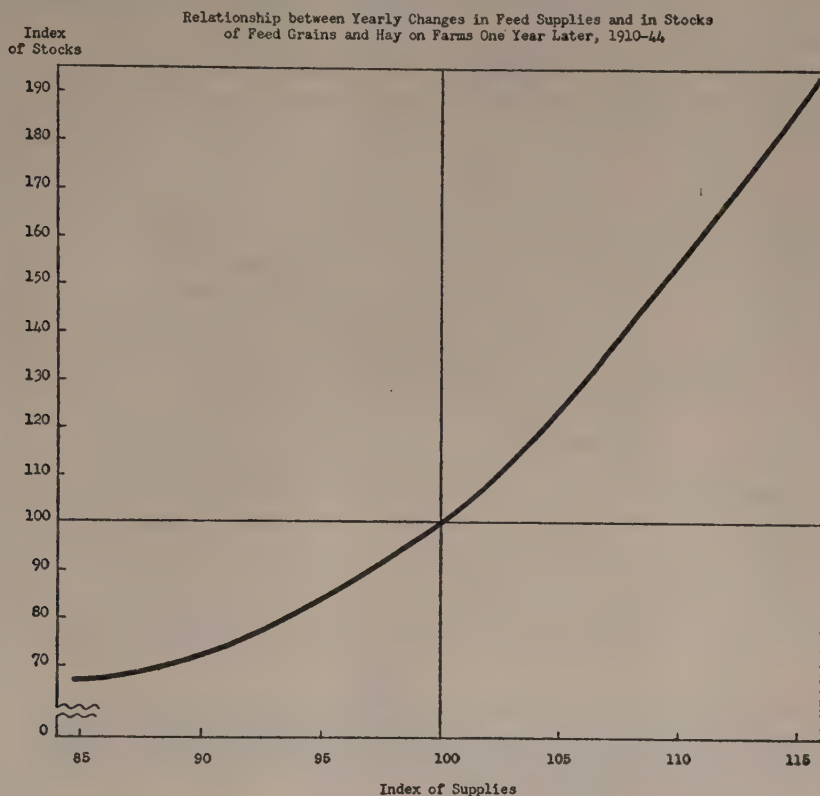
plies and in stocks does not render invalid the theory that feed consumption will approximate feed production in the preceding production period, it is now possible to add that consumption typically has been slightly less than production when this production has been "large" and that consumption typically has been slightly greater than production when production has been "small." The small magnitude of the changes in inventory precludes the possibility of there having been a substantial difference between production and consumption. The changes in stocks have not been important enough quantitatively to prevent feed consumption from changing in the same direction as supplies in over three-fourths of the years in the period being studied.³¹

It has been demonstrated both theo-

³¹ If changes of less than 5 per cent are ignored, changes were in the same direction in over nine-tenths of the years studied.

retically and statistically that changes in feed supplies (or production) effect corresponding changes in feed consumption in the same direction in the subsequent twelve months. Changes in supplies affect feed consumption in two ways. In the first place, a change in the

coefficient of feed supplies on feed consumption was $+0.68$. In other words, a change of 1 point in the index of feed supplies was accompanied on the average by a change of 0.68 points in the index of feed consumption, holding the livestock population constant.



Changes in feed supplies were accompanied by relatively large percentage fluctuations in stock of feed grains and hay on farms one year later.

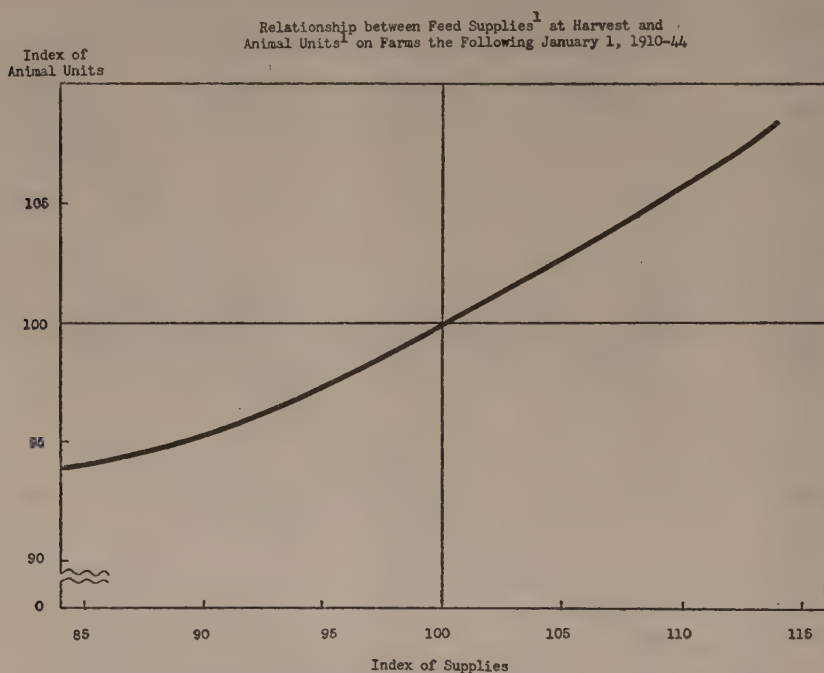
FIG. 8

volume of feed supplies becoming available in the fall of any year usually preceded a corresponding change in the same direction in feed consumption per animal unit in the following calendar year. When feed consumption, as the dependent variable, was correlated with feed supplies and animal units on farms on January 1 as the independent variables, it was found that the net regression

In the second place, the size of feed supplies affected the size of the livestock population on farms on the January 1 after the feed supplies became available. That is to say, there was some correlation between the independent variables in the correlation problem referred to in the preceding paragraph. At first thought it might seem that the nearness of the harvest of feed crops, especially corn, to

the first of the following calendar year would preclude the possibility of the size of the harvest's influencing significantly the livestock population at that date. When it is realized, however, that the size of the crop can be estimated with reasonable accuracy several weeks before

"fed" cattle may be more highly finished. That is, cattle, like hogs, may be kept on feed for longer periods and may in this way raise the figure representing the number of animal units on farms on January 1. It is clear, on the other hand, that large numbers of all classes of live-



Increases in feed supplies were followed by increases in animal-units on farms, the increase in animal units being, on the average, three-fifths of the magnitude of the increase in feed supplies. Decreases in feed supplies were followed by decreases in animal units on farms, the decrease in animal units being, on the average, two-fifths of the magnitude of the decrease in supplies.

¹Expressed as a percentage of trend.

FIG. 9

the harvest is complete, it is seen that farmers have several months before January 1 in which to adjust their livestock inventories and production plans to the size of the prospective crop. Hogs may be fed to heavier weights, with a result that many animals which might have been marketed in December are held over into January. More sows may be withheld from market in order to get more spring pigs. More cattle may be finished, and all

stock can be marketed if feed supplies and prices indicate the desirability of reducing livestock inventories.

The available statistics seem to confirm the hypothesis that significant changes in livestock numbers on farms on January 1 are effected in response to changes in the size of the preceding harvest of feed crops. In order to measure this relationship, the series for animal units on farms on January 1 and for feed

supplies were expressed in a percentage of their respective trends. The resultant percentages for the animal-unit series were sorted by the series for feed supplies. Averages for five equal groupings of the two series were obtained and plotted (Fig. 9). The line of relationship between the two variables was drawn free-hand. The results show that supplies which were, on the average, 15 per cent above trend were followed on the subsequent January 1 by livestock populations that were, on the average, 9 per cent above trend. Feed supplies that were 15 per cent below trend were followed by livestock populations that were, on the average, 6 per cent below trend (Fig. 9). Over the range of data, a rise in supplies above trend was accompanied, on the average, by a rise in livestock inventories of three-fifths the magnitude of the rise in supplies. A decline in supplies was followed by a decline in livestock inventories of two-fifths the magnitude of the decline in supplies.

Thus, changes in feed supplies affected feed consumption by causing increases in feed consumption per animal unit and in the number of animal units on farms. The gross regression coefficient of feed supplies on feed consumption in the following calendar year was 0.90. Through its effect on animal numbers and on feed consumption per animal unit, a change in feed supply of 1 per cent caused a change in feed consumption of 0.90 per cent the following year. This means that 0.10 per cent of an increase in supplies went, normally, into increases in stocks and into increased net exports. A decrease of 1 per cent supplies would be accompanied by a depletion of stocks and a decrease in net exports of 0.10 per cent of the change in supplies.³²

³² As has been previously indicated, uses of feed crops for feed, seed, and industry are insignificantly affected by changes in supplies.

The interrelationships among feed supplies, animal units on farms, and feed consumption can also be indicated by tabular analysis. By use of a two-way table, the nature of the results of the correlation analysis can be confirmed and presented in a different form. Sorting by feed supplies, expressed as a percentage of trend, and subsorting by animal units on farms on the following January 1, expressed as a percentage of trend, reveals that both feed supplies and animal units

TABLE 6
RELATIONSHIPS BETWEEN FEED SUPPLIES,
ANIMAL UNITS ON FARMS, AND FEED
CONSUMPTION 1910-44

FEED SUPPLIES*	NO. OF OBSERVA- TIONS	AVERAGE SIZE OF SUPPLIES	ANIMAL UNITS ON FARMS*	
			Large	Small
			Feed Consumption*	
Large.....	12	111	110	106
Normal....	12	101	100	99
Small.....	11	87	93	88

* Expressed as a percentage of the relevant trend.

on farms affect feed consumption in the manner already indicated (Table 6). When the index of both feed supplies and animal units on farms was "large," feed consumption was 110 per cent of its trend, on the average. When both independent variables were "small," feed consumption was only 88 per cent of its trend. When animal units on farms were above their trend, feed consumption was 110, 100, and 93 per cent of its trend when feed supplies were, respectively, "large," "normal," and "small." Similarly, when the index of animal units on farms was below its trend, the index of feed consumption was 106, 99, and 88 per cent of its trend when feed supplies were, respectively, "large," "normal,"

and "small" (Table 6). Thus, the basic deduction acquires another qualification—namely, that the extent to which a change in feed supplies is reflected in a subsequent corresponding change in feed consumption is conditioned by the number of animal units on farms on the January 1 following the harvest of the feed supplies. Again, this effect is appreciable but of minor importance when compared with the effect of changes in supplies themselves.

In the preceding paragraphs the relevant indexes have been considered in order to see whether the data tend to confirm or to contradict the deductive conclusions which had earlier been reached. The primary simplifying generalization—namely, that the price of feed is price-determined by the price of livestock and livestock products and that feed consumption in any year therefore will approximate feed production in the preceding production period—was qualified. It was seen that stocks tend to increase after "large" harvests and to decrease after "small" ones. This type of reaction necessarily caused feed con-

sumption to be less than feed production when such production was "large" and to be greater than feed production when such production was "small." Because such changes in stocks were of very minor (but not precisely measurable) significance, the simplifying generalization was confirmed and qualified. Similar qualification is necessary because of the existence of foreign trade in feedstuffs, the possibility of nonagricultural consumption of feeds, and the presence of fluctuations in the quantities of wheat (and of other "food" grains) which are fed. It can be said in rough approximation that these various causes of fluctuations in feed consumption have caused it to vary from feed production in the preceding production period by not more than 10 per cent in any year from 1910 to 1944; in most years feed consumption has more closely approximated production in the preceding production period.

Evidence has also been presented to support the second important generalization—namely, that fluctuations in feed production from year to year are primarily weather-induced.

CHAPTER III

THE NATURE AND CAUSES OF CHANGES IN THE NUMBER OF ANIMAL UNITS ON FARMS

IN THE preceding chapter an analysis of fluctuations in feed consumption was made; in this chapter an analysis of fluctuations in the number of animal units on farms will be attempted. It should be clear from a deductive consideration only that a given quantity of feed will produce varying quantities of livestock products per unit of time according to the number of animal units which are fed. That this relationship exists for extremes is obvious. It is certain, for example, that ten tons of corn would yield varying quantities of pork and lard if they were fed alternatively to one, fifty, or five thousand hogs in a single month. It is certain that the total, average, and marginal product from the use of the feed would be different in three cases. The consideration of variations in the productivity of feed for such extremes in feeding rates need not be prolonged. It will be necessary, however, to inquire whether the variations in the productivity of feed are of appreciable significance over the range of operations actually found in this country. Fortunately, empirical studies on such feed-input-output relationships are not lacking.

EMPIRICAL STUDIES OF EFFECT OF DIFFERENT RATES OF FEEDING ON PRODUCTION PER UNIT OF FEED CONSUMPTION

In regard to the productivity of feed used in beef production, Nelson's recent study is pertinent.¹ In his study Nelson

¹ Aaron B. Nelson, "Input-Output Relationships in Fattening Cattle," *Journal of Farm Economics*, XXVIII (May, 1946), 495-514.

stratified his sample of cattle according to age. He found that for two-year-old steers, yearling steers, and steer calves (all the groups included in the study) there was a steady decline in the average and in the marginal (incremental) gain in liveweight per 100 pounds of total digestible nutrients consumed throughout the fattening period.² By reading from his charts showing these relationships by age groups, it was found that 24,000 pounds of total digestible nutrients would produce in the fattening period a total gain of 4,800 pounds in the liveweight of ten steer calves. If the same amount of feed were consumed by twenty steer calves, the total gain in liveweight would be 5,520 pounds. Doubling the number of animals to which the feed was given resulted in raising the gain per unit of feed 15 per cent. Similar results were obtained in the groups of yearling and two-year-old steers (Table 7). The incremental gain per 100 pounds of digestible nutrients fed to steer calves was, on the average, 15, 18, and 20 pounds when the feed was consumed, respectively, by groups of ten, fifteen, and twenty animals. For the yearling steers the incremental gains were, 12, 14.5, and 16 pounds; for the two-year-old steers, 9, 12, and 15 pounds. This evidence indicates that, over a range of operations which undoubtedly exists in actual feeding operations, variations in the productivity of feed are appreciable. It is further indicated that for this range (and for

² Of undefined duration.

a considerable extension of this range) operations are in a stage of decreasing returns in so far as animal units are concerned. That is, the productivity function of beef animals increases at a decreasing rate over the range of observations.

In regard to input-output relationships in hog-feeding operations, the work of Atkinson is of interest. In a study entitled "The Marginal Feed Cost of Pork

an increase in the number of hogs being fed resulted in an increased product, expressed in terms of liveweight, even though feed consumption be held constant.⁴ Since the average weight of hogs marketed at Chicago has never been less than 210 pounds in any year since 1910, only three years having had average weights of less than 220 pounds,⁵ it can be seen that almost all hog production has taken place within the range covered

TABLE 7*
INPUT-OUTPUT RELATIONSHIPS IN FATTENING CATTLE

AGE GROUPS	POUNDS DIGESTIBLE NUTRIENTS CONSUMED		GAIN IN LIVELWEIGHT PER 100 POUNDS OF TOTAL DIGESTIBLE NUTRIENTS		
	Total	Per Animal	Total Gain	Average Gain	Incremental Gain
<i>Steer calves:</i>					
Group of 10.....	24,000	2,400	4,800	20.0	15.0
Group of 15.....	24,000	1,600	5,280	22.0	18.0
Group of 20.....	24,000	1,200	5,520	23.0	20.0
<i>Yearling steers:</i>					
Group of 10.....	24,000	2,400	3,840	16.0	12.0
Group of 15.....	24,000	1,600	4,320	18.0	14.5
Group of 20.....	24,000	1,200	4,680	19.5	16.0
<i>Two-year-old steers:</i>					
Group of 10.....	24,000	2,400	3,600	15.0	9.0
Group of 15.....	24,000	1,600	4,080	17.0	12.0
Group of 20.....	24,000	1,200	4,320	18.0	15.0

* Source: Nelson, *op. cit.*, p. 502.

and Lard" he states that the liveweight of hogs increases at a decreasing rate above a 175-pound weight for the butcher hog with additional equal increments of feed.³ This form of the statement may not reveal at once the necessary corollary that, with a given quantity of feed, an increase in the number of hogs being fed will result in an increase in the gain in liveweight, *ceteris paribus*. In this study Atkinson demonstrated, obliquely to be sure, that for hogs over 175 pounds

by the Atkinson study.⁶ Thus, for hogs

⁴ This discussion is limited to relationships between feed inputs and outputs expressed in pounds of *liveweight*. The principles hold for output in terms of edible product as well, but the indexes and subsequent analyses of this study concern liveweight only. For a detailed discussion of these relationships in other terms see L. Jay Atkinson and John Klein, *Feed Consumption and the Production of Pork and Lard* (United States Department of Agriculture Technical Bull. 917 [Washington, D.C., January, 1946]).

⁵ Drovers Journal Publishing Co., *Yearbook of Figures of the Livestock Trade, 1945* (Chicago, [1946]), p. 71.

⁶ In an earlier study Atkinson and Klein found that the productivity function of feed increased at a decreasing rate at all weights after weaning. See

³ L. Jay Atkinson, "The Marginal Feed Cost of Pork and Lard," *Journal of Farm Economics*, XXVII (May, 1945), 379.

as well as for beef cattle a given quantity of feed, k , will yield a greater live-weight of livestock if it is consumed by $n + 1$ animals than by n animals.

The rate at which output decreases with additional units of input is more rapid in dairying than in either of the two types of livestock production already discussed. In an elaborate and prolonged series of experiments Jensen and his associates attempted to measure the input-output relationships in dairying.⁷ They found that, at any rate of feeding which was sufficient to produce milk, additional increments of feed produced progressively smaller increments in the production of milk. They go on to say: "The response to increased feed was less at the high levels than at the low levels—0.6 pounds of 4 per cent fat—corrected milk for each additional pound of digestible nutrients at the highest level and 1.7 pounds at the lowest level."⁸ This study, like the ones previously mentioned, indicates that an increase in the number of animals (holding feed consumption constant) will result in an increased production of livestock products. Empirical studies on lamb feeding, poultry production, and other types of livestock enterprises are not available, but there is no reason to believe that the nature of the input-output relationships in such enterprises is different from those in the three most important types of livestock production: beef production, hog production, and dairying.

L. Jay Atkinson and J. Klein, *Feed Consumption and Marketing Weight of Hogs* (United States Department of Agriculture Technical Bull. 894 [Washington, D.C., July, 1945]).

⁷ Einar Jensen *et al.*, *Input-Output Relationships in Milk Production* (United States Department of Agriculture Technical Bull. 815 [Washington, D.C., May, 1942]).

⁸ *Ibid.*, p. 86.

If these relationships exist for the various individual types of livestock, indexes purporting to represent aggregates of feed consumption and livestock production for all types of livestock should reflect a similar relationship between inputs of feed and outputs of product. That is, increased feed consumption per animal unit should result in smaller livestock production per unit of feed consumption. In order to test this hypothesis, the two ratios were expressed in the percentage of the preceding year and were plotted for the thirty-five-year period 1910-44. With striking regularity an increase in the rate of feeding was accompanied by a decrease in production per unit of consumption (Fig. 10). Similarly, a decrease in the rate of feeding was accompanied by an increased productivity per unit of feed consumed. In so far as the results of the macroanalysis conform to those of the empirical studies, the validity of the indexes used is indicated. The evidence shows that the yearly fluctuations in rates of feeding which have taken place in this country have caused fluctuations of appreciable magnitude in the production of livestock products per unit of feed consumption. Because rates of feeding are determined not only by the volume of feed consumption but also by the number of animals being fed, it becomes necessary for this analysis to inquire into the causes of yearly fluctuations in the livestock population.

NATURE OF FLUCTUATIONS IN THE INDEX OF ALL ANIMAL UNITS ON FARMS

Using conventional statistical terminology, it can be said that, after observing and measuring the data, fluctuations in the index of all animal units on farms are of three kinds: cyclical, random, and secular. In the subsequent

pages these types of fluctuations will be analyzed in the hope that, by understanding them, light will be cast on the underlying causes of the behavior of one factor—the number of animal units—of the two that determine yearly fluctuations in livestock production.

Many writers have commented upon the presence of fairly regular cyclical

fifteen years when measured from peak to peak) with the exception of the last cycle. During this latter period there occurred two severe droughts and World War II, events which have been and will be called upon to explain economic fluctuations whose eccentricities are far greater than those in this index. The analysis of these cycles will be made by

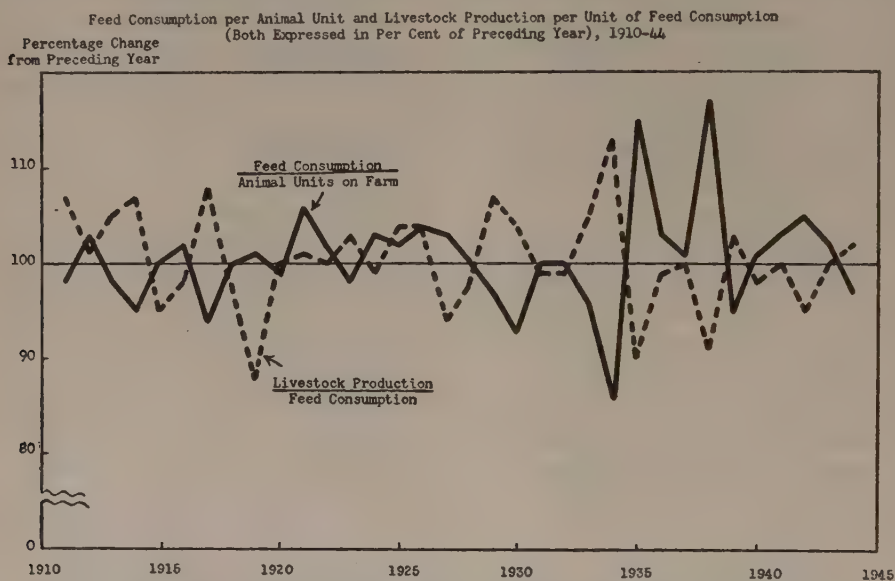
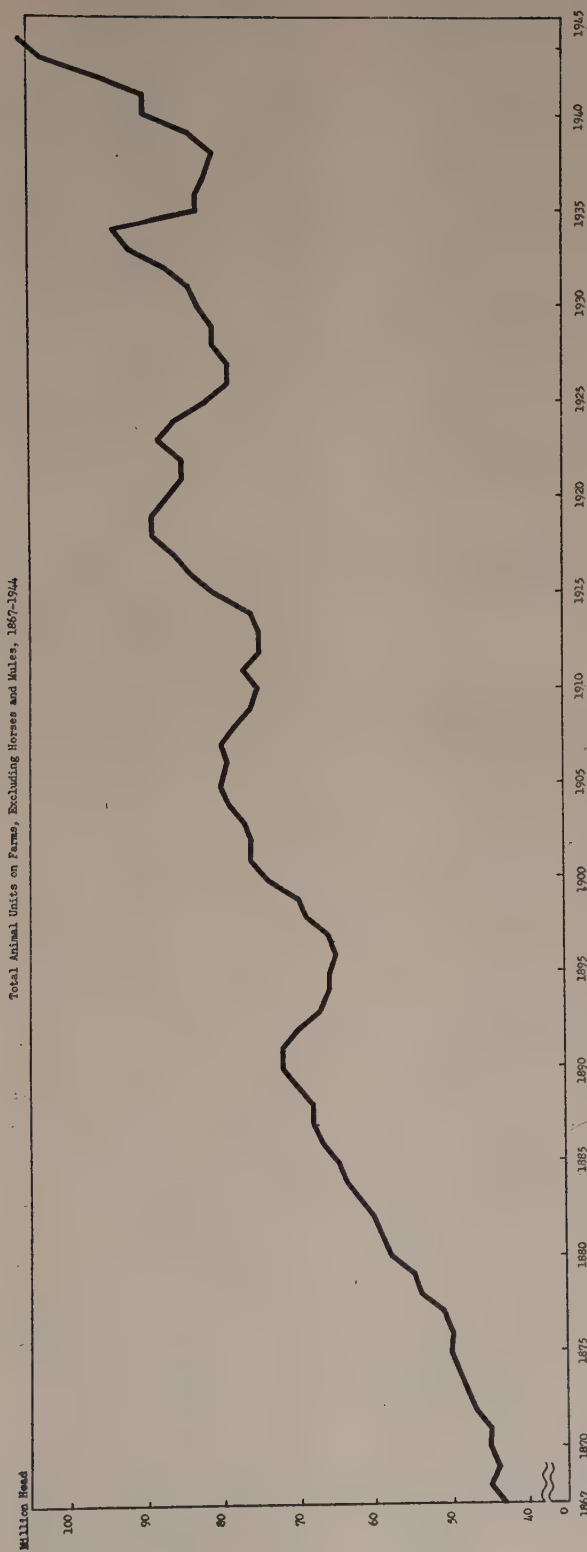


FIG. 10

fluctuations in the numbers of the various classes of livestock found on farms in this country. Whether it is true or not that cycles in numbers exist for all the classes of livestock for which cycles have been described, it is clear that the index of all animal units on farms does reveal marked and fairly regular cyclical movements (Fig. 11). Four discernible major cycles have occurred since 1891. Cyclical highs occurred in 1891, 1905, 1919, 1934, and 1944. Cyclical lows occurred in 1896, 1912, 1927, and 1938. These cycles were uniform in length (about

analyzing the cyclical fluctuations in the numbers of the various classes of livestock which make up the index. Such an analysis will reveal which classes of livestock most significantly affect the major cyclical pattern in the index of all animal units and will thus help in limiting the field for further exploration in the search for underlying causes.

In order to show the effect of changes in each component part of the index of total animal units on farms on the major cyclical pattern of this index, the following method was used:



Before 1890 an upward trend was evident and proceeded with few interruptions; subsequently, marked cyclical fluctuations were present.

FIG. II

1. Trends for each component part of the index of total animal units and for this index itself were computed.

2. Deviations of the index of total animal units above and below this trend line at the cyclical peaks and troughs were computed.

3. Deviations of each component part of the index above or below their respective trends were computed for the same years in which the total index had either cyclical peaks or troughs.

4. The proportionate contribution of the deviations of the component parts (as described in 3) to the deviations in the total index (as described in 2) were computed by dividing the deviations of the component parts of the index by the corresponding deviation in the total index.

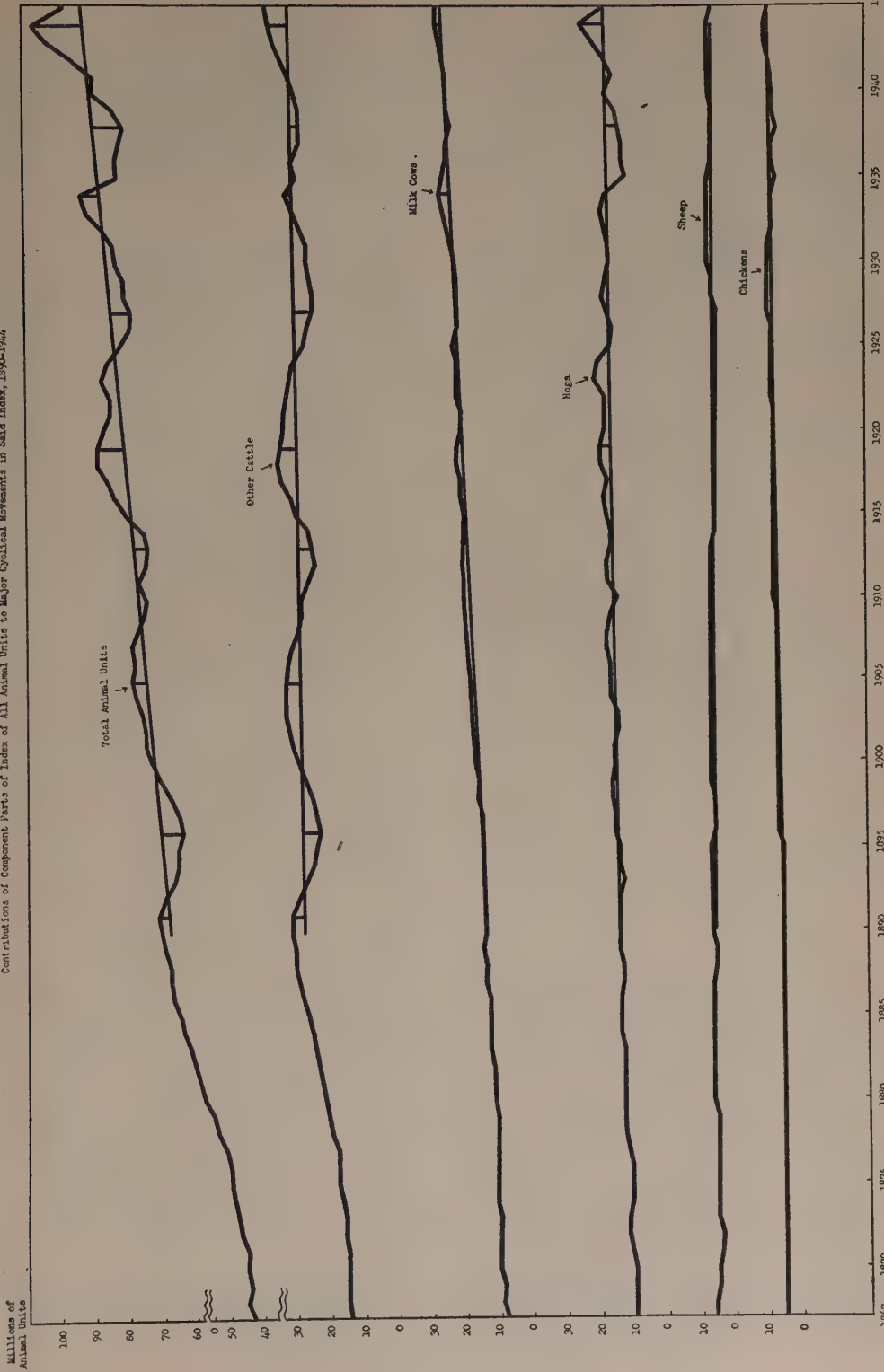
5. An average of the proportionate contributions to the total cyclical pattern in all peak or trough years by each component part of the total index was computed.

Before 1890 there were no cycles of significant magnitude, the series on total animal units being marked by a steady and pronounced upward trend. After 1891, however, the trend was reversed, and the number of animal units on farms declined for five successive years. Subsequently, the index for all animal units showed a periodic rise and fall above and below its trend line (Fig. 11). The year 1891, therefore, will be considered as the peak and starting-point for the first livestock cycle. In that year the total number of animal units on farms was three million greater than trend. The number of "other cattle" in this year was two and a half million animal units above trend. The peak of the two cycles coincided, and the amplitude of the cattle cycle accounted for over 80 per cent of the deviation in the index of total animal units from its trend line. Numbers of milch cows and sheep were both slightly above their respective trends and accounted for the rest of the deviation in the index of total animal units (Fig. 12).

At the bottom of the cycle, 1896, the index of total animal units was six mil-

lion units below its trend. In the same year the number of "other cattle" expressed in animal units was five million units below its trend. Again the turning-points of these two series coincided; again fluctuations in "other cattle" accounted for over 80 per cent of the deviation in the index of all animal units. The correspondence between the high and low points in the two series—total animal units and "other cattle"—was very close in all subsequent cycles, the difference between them never exceeding one year. In most of these cycles fluctuations in "other cattle" accounted for the major part of the deviations in the index of all animal units above or below its trend. Considering all five peaks, fluctuations in numbers of "other cattle" accounted for 62 per cent of the deviations of the index of animal units above its trend. Only in the peak years of 1934 and 1944 did "other cattle" fail to account for over 60 per cent of the deviation in the index of all animal units. In 1934 milk cows accounted for about 50 per cent of this deviation. It must be remembered however, that many so-called milk cows are dual-purpose cattle and that some of the characteristics of beef cattle fluctuations inhere to a lesser degree in the series called "milk cows." In 1944 hogs accounted for almost 50 per cent of the deviations in the index of all animal units, hog numbers having been sharply increased following the record-breaking corn crops of 1942-43. In so far as the increase in hog numbers was made possible by the size of the preceding corn crops, and in so far as hog production was encouraged more strongly than other types of livestock production by governmental price regulations—and there is evidence that this was true⁹—the deviation in hog

⁹ C. W. Crickman, *Feed Grains and Meat Animals in War and Peace* (Washington, D.C.: United States Department of Agriculture, November, 1945), p. 27.



Most of the major cyclical fluctuations in the index of all animal units on farms was due to the cycle in numbers of "other cattle."

FIG. 12

numbers above its trend line cannot be described as part of a typical cyclical pattern in fluctuations in hog numbers. One influence was the weather, and the other was governmental action, neither factor being periodic or predictable.

When the four cyclical troughs in the index of all animal units were analyzed, it was found that "other cattle" accounted for 72 per cent of the deviations in the index. In only one trough (that of 1938) did the deviation in "other cattle" below its trend fail to account for over 80 per cent of the deviation in the index of all animal units below its trend. In that year the deviation in "other cattle" accounted for only 22 per cent of the deviation in the index of all animal units, the main part of this latter deviation being attributable to the very low level of the hog population. Again the weather can be designated as the causal agent. The droughts of 1934 and 1936, with their corn crops of about 50 per cent of normal, caused an unprecedentedly sharp reduction in hog numbers as well as a depletion of the country's stocks of feed grains. As a result, hog numbers in a random, weather-induced fluctuation caused the cycle in all animal units to be of much greater magnitude than would otherwise have been the case.

The importance of the cycle in "other cattle" in determining the rhythm and amplitude of the cycle in the index of all animal units can be seen better, perhaps, in the following way. Straight-line trends for the numbers of all classes of livestock were computed. The trend values for all classes except "other cattle" were added to the actual numbers of "other cattle" on farms. The resulting series was then compared with the original index of all animal units. When this was done, the remarkable similarity between the cyclical movements of the two series be-

came apparent (Fig. 13). At all times the rhythm, as indicated by the cyclical turning-points, was the same, and only during the drought of the 1930's and World War II was the amplitude markedly different.

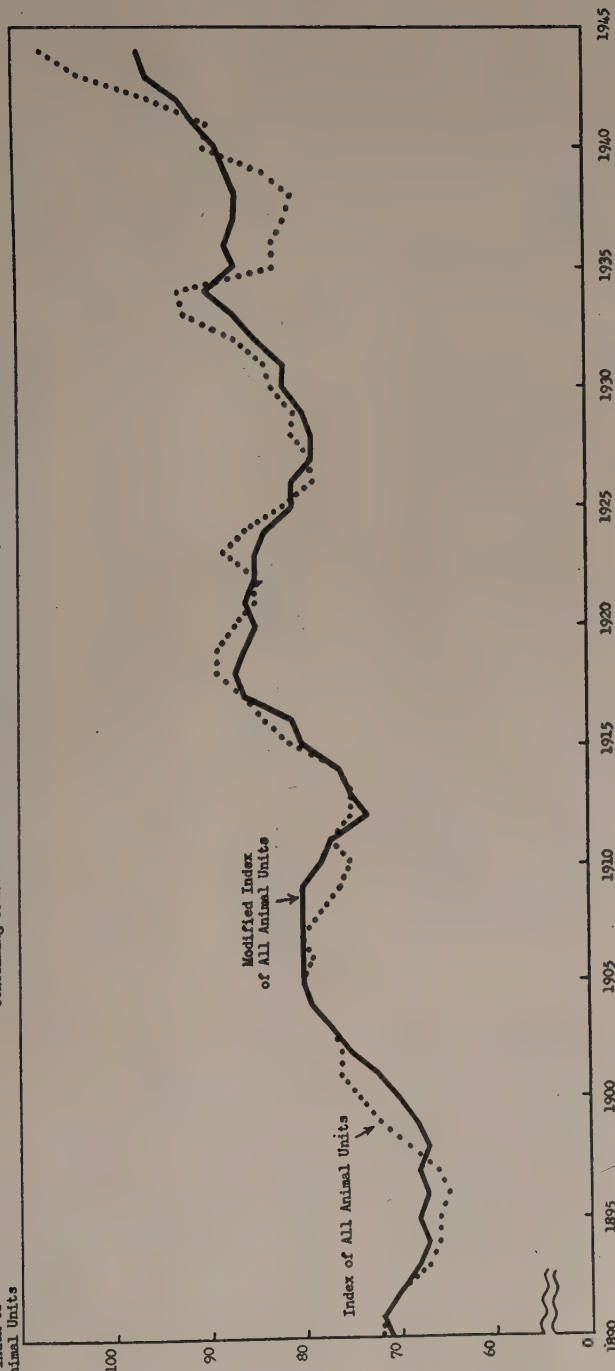
THEORIES OF THE CATTLE CYCLE

Now that it has been established that it is the cycle in numbers of "other cattle"¹⁰ that accounts for the major cyclical fluctuations in numbers of all animal units on farms, an analysis of the factors causing these cycles in numbers of "other cattle" will be attempted. There is found among the economists who theorize about the nature of the causative agents of the cycle in cattle numbers the same dichotomy which exists among theorists of the business cycle. Some believe that the cycles in numbers are induced by exogenous factors—factors not an inherent part of the cattle industry. Others believe that the cycle can be adequately explained by the nature of the production (of cattle) process itself. Almost all theorists agree that cattle numbers are inversely correlated with their value per head and that the two series have an interrelation of mutual causality; that is, changes in the value of cattle cause changes in the cattle population and that these latter changes, in turn, affect cattle values. A difference of opinion exists, however, as to the relative importance of each series in affecting the other. Those who stress the importance of exogenous factors believe that changes in cattle numbers have a relatively minor influence on their value per head, while the major influence comes from changes in demand. Those who believe in the exist-

¹⁰ This term is defined by the United States Department of Agriculture as all cattle other than cows and heifers two years old or over which are kept for milk.

Index of All Animal Units on Farms and a Modification of This Index
Containing Trend Values for All Classes of Livestock Except "Other Cattle," 1890-1944

Index of
Animal Units



The removal of all cyclical and random fluctuations from the series on numbers of all classes of livestock except "other cattle" reveals that the major cyclical pattern in the index is due to the cycle of "other cattle."

FIG. 13

ence of an inherent cyclical pattern in the cattle industry itself must, of course, posit that the major influence on value per head is changes in cattle numbers. First, the theory of exogenous causes will be examined; next, the theory of an inherent cyclical influence will be discussed; and, finally, an evaluation of the two theories and a synthesis will be made.

Probably the leading exponent of the theory of exogenous causation is John A. Hopkins, Jr. In his *A Statistical Study of the Prices and Production of Beef Cattle*, Hopkins attempts to confirm his theory statistically:

The cattle cycles of the past 60 years are apparently due to forces outside of the cattle industry, but these forces or conditions which have caused the major crises in the cattle industry do not seem to be related to any regularly recurrent phenomena. The prices of cattle are affected, of course, by the activity or depression of business, and are therefore influenced by the general business cycles. This will probably account for a minor series of cycles but not for the major cycles which have been 12 to 15 years in length. No phenomena of a regularly recurrent nature and with a periodicity of 12 to 15 years have come to light to explain the major cycles. The cattle price cycles are irregular in length and in amplitude, and for each there seems to be a different reason.¹¹

Hopkins essays assigning a specific cause to each peak or trough in cattle prices. The peak in 1870 "was the result of the large demand for cattle during the boom period at the end of the Civil War."¹² To what boom he refers is not clear, for the index of business activity fluctuated within a range of 5 per cent above and below normal and prices declined steadily from 1865 until the fall

of 1871. Cattle prices declined steadily from their peak in 1870 to a trough in 1878. This decline was caused, says Hopkins, by the collapse of the postwar boom and by the hard times of the early 1870's. Once again it is hard to agree with Hopkins' diagnosis. Although it is true that there was a rather severe business depression in the 1870's, business activity did not drop below its trend line until November, 1873. During 1871, 1872, and most of 1873, American business was enjoying its biggest boom in thirty years.¹³ Prices, too, rose during most of this period.¹⁴ Cattle prices started to recover in 1878, while business activity was fluctuating near its depression low and while the price level was still declining. Business and prices did not reverse themselves and return to "normal" until the second half of 1879, more than a year after the revival in cattle prices.¹⁵

Hopkins explains subsequent cycles with an equal imprecision and lack of cogency. The next price cycle reached its peak in July, 1884, and was explained, according to him, by the increase in demand for cattle which accompanied the settlement of the western ranges.¹⁶ That a secular or gradual and steady structural

¹³ The business index used is that of Leonard P. Ayres of the Cleveland Trust Company.

¹⁴ The price index used is the Warren-Pearson index published by Cornell University.

¹⁵ Some confusion may result in this discussion of theories of the cattle cycle because the cycle is sometimes defined in terms of prices, sometimes in terms of numbers on farms, and occasionally in terms of marketings. Although many writers have not recognized the necessary interrelationships between cyclical movements in these three series, it will be shown that these various cycles are really different aspects of the cattle cycle. Therefore, although the interest of this study is focused on fluctuations in cattle numbers, it seems desirable to examine critically the various cyclical theories, even though some of them do not ostensibly and explicity purport to explain fluctuation in cattle numbers.

¹¹ John A. Hopkins, Jr., *A Statistical Study of the Prices and Production of Beef Cattle* (Iowa State College of Agricultural and Mechanic Arts Research Bull. 101 [Ames, Iowa, December, 1926]), p. 351.

¹² *Ibid.*

¹⁶ *Op. cit.*, p. 352.

change such as that caused by the settlement of the western ranges could cause a cyclical fluctuation in cattle prices is difficult to understand. Another thing which weakens the persuasiveness of Hopkins' hypothesis is the fact that changes in business activity, to which he ascribed such great importance in explaining the previous cattle cycle, seemingly had no effect in this second cycle. While cattle prices were reaching their peak, business activity was approaching the trough of depression. The price level, which had been declining steadily since the last months of 1882, continued to fall until 1886. This lack of synchronization between business activity and cattle prices is even more striking, perhaps, in the 1890's, when cattle prices started a steady and substantial rise in the face of business depression of a greater severity than any before in our history.

Hopkins explains subsequent cycles in terms of changes in demand or in population, wars, etc. At no time is statistical evidence presented and seldom is the influence of factors, other than the somewhat arbitrarily chosen causal agent, considered. In the absence of any reliable measure of the demand for cattle, or the effect of population changes, or of changes in business activity, one must view with extreme caution any conclusion which posits a causal relationship between these various factors and changes in cattle prices or numbers. Hopkins seems to have proceeded on the basis of "reasonable" assumption rather than upon a rigorous examination of the available evidence. It seems probable that a more consistent and convincing explanation of the fairly regular fourteen- to sixteen-year cycles in cattle numbers can be found.

Professor F. L. Thomsen represents the school of endogenous causation. In

regard to analyses such as Hopkins' he says:

It appears to many . . . that these episodic influences have served merely to affect the length or emphasize the degree of the cyclical movements of cattle production and prices and that there is a residual movement of cattle prices which is attributable to the truly cyclical nature of cattle production.¹⁷

Thomsen does not, however, explain exactly what the causes of the cyclical nature of the production process are; nor does he attempt any generalizations about the relationships between this production process and certain affecting exogenous factors, the most important of which is the weather.

More sophisticated attempts to explain the cyclical nature of certain agricultural series, including cattle and hog numbers, are found in the various formulations of the "cobweb theorem." Variants of this theorem have appeared in the literature since 1930, and a substantial literature of criticism and controversy has developed.¹⁸ These controversies and the theory itself are too well known to require elaboration here. It does seem desirable, however, to examine the validity of Ezekiel's assertion that the theory provides an adequate explanation of the cattle cycle, recognizing, of course, that no economist, and certainly not Ezekiel, claims that the relevant series can in reality operate with the smoothness and regularity of a theoretical model. Ezekiel states three conditions which must prevail if the theorem is to be used as an explanation of price behavior. These conditions are the following:

¹⁷ F. L. Thomsen, *Agricultural Prices* (New York and London: McGraw-Hill Book Co., Inc., 1936), p. 360.

¹⁸ For a bibliography on this subject see Mordecai Ezekiel, "The Cobweb Theorem," *Quarterly Journal of Economics*, February, 1938, pp. 255-56.

1. The producer bases plans for future production on the assumption that present prices will continue and that his own production will not affect the market.

2. The existence of an irreducible time lag of "at least one full period" between the commitment of resources to produce and the possibility of greatly altering this commitment.

3. The price is "set by the supply available."

Ezekiel recognizes that these conditions do not exist without qualification for any commodity, and he lists the more common and important qualifications for agricultural commodities.¹⁹ Nevertheless, by implication, Ezekiel leads the reader to believe that the theorem can serve as a useful frame of reference in any attempt to understand the cattle cycle, and as evidence he presents a chart of the fairly regular fourteen- to sixteen-year cycle in the purchasing power of cattle.²⁰ Ezekiel does not apply the theory to the actual data in this chart and leaves it to the unwary reader to assume that the theory can be used as a theoretical explanation of the very evident cycle.

The theory cannot be so used, however. Ezekiel, in his theoretical formulation, considers interrelationships between only two variables: prices and production. This leads to reasoning such as the following in regard to the case of a "two-period" lag in supply:

Since two years are required for the result of the first year to appear, the supplies for the first two years, Q_1 and Q_2 , must be assumed, with the resulting prices P_1 and P_2 . In response to the initial low price, production two years later, in the third period, is reduced to Q_3 , with the resulting high price, P_3 . This is followed in the fifth year by a corresponding increase to Q_5 , with a corresponding low price, P_5 . Since this is a subclass of Class 1, the reaction continues in alternate years around the same pathway, P_5 , Q_7 , P_7 , Q_9 ; etc. Likewise, the price and supply of the second year, Q_2 and P_2 , are fol-

lowed two years later by reduced supply, Q_4 , and increased price, P_4 ; four years later by Q_6 and P_6 , and so on *ad infinitum*.²¹

Reasoning such as this leads to the ambiguous assertions that "cases . . . with a one-year lag in response all produce two-year cycles. . . . Case 1a, with a two-year lag in production, has a four-year period from peak to peak; and Case 3c, with a three-year lag, a six-year period."²² Although it is clear that the phrases "lag in response" and "lag in production" are equivalent expressions, it is not clear what they mean. A careful reading of the text indicates that these "lags" are time periods equal in length to the time between decision of a producer to produce a commodity and the completion of the production of that commodity. For most field crops this lag is one year. For livestock the lag is equal to the period of gestation plus the marketing age. The substitution of this more precise phrasing for Ezekiel's ambiguities makes it clear, perhaps, why Ezekiel merely presents a chart of the cattle cycle without attempting to use it as a test of this theory. If he had applied his theory to the chart, he would have had to maintain that the "lag" in the case of cattle is seven to eight years. The lag is certainly not so long. In the earlier part of the period in the chart (1875-1900), cattle other than milch cows were probably marketed at an average age of about three years. In the latter part of this period the average age was probably somewhat less. In any case, the actual cycle is far longer than the theorem would have led one to expect.

In a very carefully reasoned consideration of this relationship between the length of the theoretical cycle and the

¹⁹ *Ibid.*, pp. 272-73.

²⁰ *Ibid.*, p. 270.

²¹ *Ibid.*, p. 266.

²² *Ibid.*, p. 268.

length of an actually observed cycle, Coase and Fowler come to the same conclusion—namely, that the cobweb theorem does not explain observed facts. In their study of the pig cycle in Great Britain, they say:

We have shown that if farmers acted according to the assumptions of the "Cobweb Theorem," the technical conditions are such that a cycle of about two years would arise. Since it is generally agreed that the cycle is much longer than this, it is clear that this furnishes additional grounds for rejecting the theorem.²³

The failure of the theorem to explain satisfactorily observed cycles in the purchasing power and/or number of cattle, hogs, or other livestock can be attributed, it is believed, to a failure to distinguish between production and marketings and the different effects of these factors on prices and the responses of producers. In the following pages an attempt will be made to formulate a theory of the nature of cyclical fluctuations in cattle (and other livestock numbers). The theory will try to make clear the nature of the interrelationships among value, marketings, and numbers on farms (or production). For heuristic reasons a theoretic model of the cattle cycle will be constructed. Subsequently, the validity of the assumptions upon which the model is based and the correctness of the model as a whole will be tested by comparison with the available statistical evidence. Next, the effect of the more important exogenous factors on the model will be considered.

First, let it be assumed that there is complete stability of everything that affects the value of cattle. The productive capacity of pastures and ranges, the tastes of the people, their income and its

distribution, the technology of production, freight rates, legislation, the value of all other commodities, and numberless other factors must, of course, be stabilized. Assuming this stability and that equilibrium exists, cattle numbers, prices, and marketings would remain constant from year to year, exhibiting no cyclical characteristics. Into this equilibrium let there be introduced a disturbance, such as a change in the carrying capacity of ranges which affects the decisions of farmers. Let it be assumed that favorable weather increases materially the carrying capacity of ranges and pastures and that farmers as a consequence decide to increase their breeding herds. This increase in breeding herds can normally be effected only by holding back from market animals that customarily would have been sold. In other words, the decision to accumulate animals on farms causes a decline in marketings. This decline in marketings will, in turn, raise the value of animals that are marketed, *ceteris paribus*. Thus, the initial disturbance of the equilibrium causes in this case an incipient accumulation of animals on farms, a decline in marketings, and a rise in value.

In order to theorize about the subsequent effects of this initial disturbance on cattle numbers, marketings, and values, it first is necessary to determine the characteristic reaction by cattle producers to such value changes. A farmer might react to an increase in the value of cattle by increasing his marketings at the expense of a liquidation of some of his herd. Or, conversely, he might increase his herd at the expense of decreased current marketings in the hope of increasing production in the future. The evidence which is available indicates that American farmers have characteristically reacted in this latter fashion. When the value of cattle

²³ R. H. Coase and F. F. Fowler, "The Pig-Cycle in Great Britain: An Explanation," *Economica*, February, 1937, p. 77.

has risen above a trend or "normal" line, farmers have tended to increase the number of beef cattle kept on farms. Conversely, a decline in prices below "normal" has typically effected some liquidation of existing herds (Fig. 14). Applying this type of reaction to the model, it will be seen that the initial decline in marketings and rise in value would create further accumulation on farms, further decreases in marketings, and a further rise in values. The initial disturbance, due to an exogenous force, created changes in cattle numbers, marketings, and values which *in themselves* generated further changes in the same direction—a direction away from the equilibrium level.

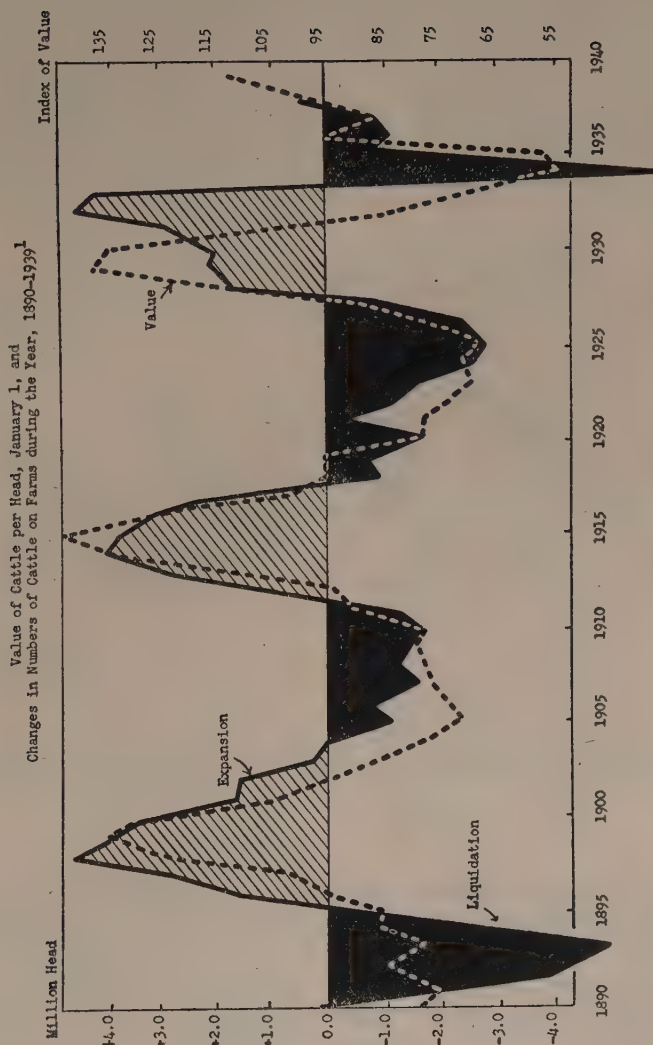
Before proceeding with the subsequent developments in the cycle, it might be well to note parenthetically that the results would be almost the same if the initial disturbance were of a sort that affected values directly rather than marketings. A change in the tastes of the public would constitute a disturbance of this sort. If the value of cattle rose as a result of an increase in the demand for them, there probably would be some time lag between the rise in value and the actual beginning of the accumulation process. This lag would affect the timing slightly; but, once the decision to accumulate animals was made, the effect on marketings and further effects on cattle values would be the same as when the weather was the disturbing influence. The subsequent development of the cycle would be the same in the two cases, except that the so-called "equilibrium level" itself would be changed if the initial disturbance were a change in demand. Consequently, in this latter case the cyclical fluctuations would be around a different equilibrium position. The differences between cycles initiated by these two types of disturbances can be seen in Figures 15 and 16. The dif-

ferences, such as they are, exist because the *response to price* (or value) changes is less immediate than the *response of prices* to changes in other factors—marketings, for instance.

Keeping these similarities and differences in mind, it is now possible to proceed with the subsequent developments of the cycle. Animals were held back from market in order to increase production and to increase future marketings. In the earlier years of the period being studied, 1890-1944, the increased marketings would probably not occur until nearly four years after the initial expansion in inventories.²⁴ In the latter part of the period, when there was an increased tendency to market beef at earlier ages, the increased marketings would probably occur in somewhat less time—in about three years perhaps. Thus, in three to four years after inventories started to expand and marketings started to decline, the increased production on farms resulting from the greater breeding capacity of the herds can be expected to reverse the downward trend in marketings. All other things remaining constant, the increased marketings will cause the value of beef cattle to decline. (The preceding relationships are illustrated in idealized form in Fig. 15.)

It is now necessary to consider the relative significance of the *direction* of the change in value as compared with the absolute *level* of value in affecting farmers' decisions. Since in the abstract model the initial disturbance caused both an upward movement in the value of cattle and a rise in its level above its "normal" or equilibrium status, there was no need to distinguish between the effects of

²⁴ If it is assumed that cattle were marketed at an average age of three years, the progeny of the animals originally withheld from market would be marketed about four years after the decision to increase production was made.



Expansion took place when value was above "normal," regardless of the direction of the change in value, and liquidation when value was below "normal," regardless of the direction of change.

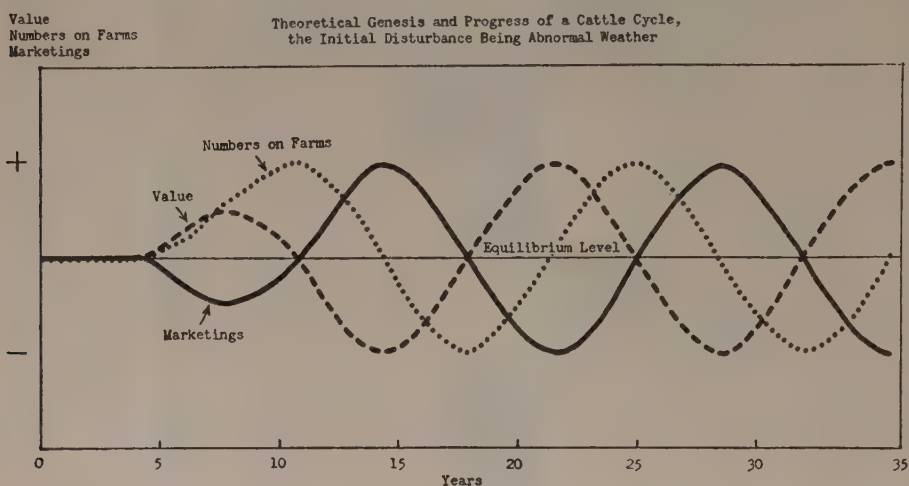
¹Cf. F. A. Pearson and W. I. Myers, "Prices," *Farm Economics*, No. 112, April, 1939, p. 2737.

FIG. 14

change and level. At this stage, however, value is declining while it is still substantially above the "normal" level, and some assumption must be made as to the characteristic reaction of farmers. It will be postulated here that farmers will continue to expand their inventories of cattle as long as the value of cattle is above the "normal" or equilibrium level. The downward movement in prices will have

further declines in prices and by a further lessening of the rate of expansion. When cattle marketings have increased to the equilibrium level, values will have declined to this level and cattle numbers will have reached a peak.

Marketings will continue to rise because of the peak level of breeding herds and because animals will no longer be withheld from the market in order to in-



The interrelationships between cattle values, farmers' inventory policies, and the volume of cattle marketing, together with the necessary lag between planning of production and its effectuation, explain the presence and length of the cattle cycle.

FIG. 15

its effect in lessening the rate of expansion and, of course, the absolute magnitude of the increments. The validity of this postulate will be examined later.

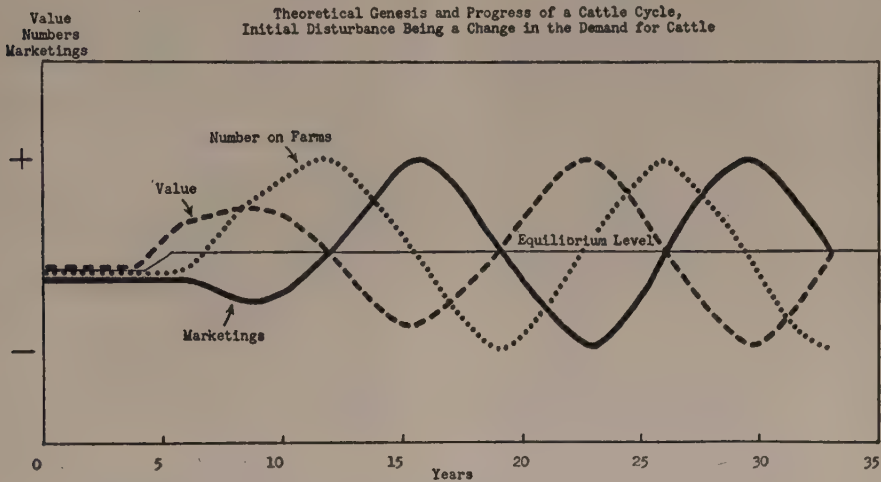
Proceeding on the basis of this second assumption, the incipient rise in marketings and fall in prices will be accompanied by further increases in numbers of cattle on farms, although these increases will be at a decreasing rate (Fig. 15). Marketings will continue to increase as the productive capacity of the breeding herds grows and as increments to these herds decrease. These further increases in marketings will be accompanied by

crease cattle inventories. The continued rise in marketings to above the equilibrium level will cause further declines in cattle values to below the equilibrium level. This decline will, according to the stated assumptions, cause some liquidation of existing herds. Numbers of cattle will for the first time, about seven years after the initial disturbance of the equilibrium, start to decline. As herds are liquidated, marketings will continue to rise. So long as breeding herds remain above the equilibrium level and are being liquidated, marketings will rise and cattle values will decline.

As numbers on farms reach the equilibrium level, marketings will have reached their peak and values their nadir (Fig. 15). At this point the productive capacity of breeding herds will have declined so much that the lessening in the flow to market of young animals will more than offset the continued liquidation of breeding stock. Marketings will therefore start to decline, and with this

fourteen years, assuming that cattle are marketed at an average age of about two and one-half years.

Before introducing disturbing exogenous influences into the schema, two basic assumptions will be tested. As to the first assumption, both authority and statistics lend confirmation. Professor Shepherd states that "high beef cattle values at the farm lead to increases in



The pattern is the same as that when the initial disturbance did not affect value directly, although the timing of movements in the series is somewhat different.

FIG. 16

decline will come a reversal of the downward movement in the value of cattle. As values start to rise, the rate of liquidation of cattle inventories lessens, although liquidation will continue until values are once again at the equilibrium level. Marketings will continue to decline and values to rise until they simultaneously reach the equilibrium level. At this point cattle numbers will be at their lowest. The rise of values above the equilibrium level will start an expansion of inventories once again. Thus, the round of the cattle cycle is complete (Fig. 15). The complete cycle requires

beef cattle numbers . . . low beef cattle prices lead to liquidation of herds."²⁵ In like manner, Professor Pearson states: "When the purchasing power [of beef cattle] is high, animals are held back . . . when the purchasing power is low, breeding stock is liquidated."²⁶

The statistical evidence, too, is clear. If the value series is related to a series representing accumulation and liquidation, the confusion which sometimes re-

²⁵ G. S. Shepherd, *Agricultural Price Analysis* (Ames, Iowa: Iowa State College Press, 1941), p. 65.

²⁶ F. A. Pearson, "Farm Prices," *Farm Economics*, No. 106, April, 1938, pp. 257-58.

sults from an inspection of the series for value and cattle numbers can be avoided (Fig. 14). This figure shows that cattle values above normal were accompanied with great regularity by an accumulation of cattle on farms. Values that were less than normal were accompanied with equally great regularity by liquidation of breeding stock. This figure is useful, too, in indicating the validity of the second assumption—namely, that farmers will accumulate cattle when values are above normal and will liquidate cattle when values are below normal, regardless of the direction of the change in value. It can be seen that the highs and lows of value are typically concomitant with the most rapid accumulation and liquidation, respectively; that is, the peaks in value corresponded fairly closely in time with the greatest increments to herds, while the troughs in value corresponded with the greatest decrements. Accumulation characteristically continued, however, as long as values were above normal; liquidation, as long as values were below normal. If these assumptions be granted, a pattern of the type found in the abstract model which has been presented will necessarily follow.

In regard to the implicit *ceteris paribus* assumption upon which the model is based, it cannot be seriously proposed that the assumption is valid over any significant period of time. Nor is it suggested that the movements through time of the three series need be with the complete regularity that is found in Figure 15. Nor is it necessary that the amplitudes of the cyclical fluctuations be that which is indicated or that the series have fluctuations of equal amplitude. Nor does the theory require that the periods of accumulation and liquidation be of equal length. It is also almost certain that there

exists a lag between the movements in values and in cattle numbers—that is, the response is undoubtedly not simultaneous. Variations of these sorts do not in any way, however, destroy the validity of the model as an illustration of the types of interrelationships which are responsible for the cycle. The model was constructed to indicate the nature of the cattle-production process, to give some explanation for the length of the cycle, and to provide a background against which the influence of impinging exogenous factors can be appraised.

The most important variable which has not been considered is undoubtedly the weather. In the construction of the model it was necessary to assume that the carrying and productive capacity of pastures and ranges was constant at a level sufficient to permit the carrying of the maximum number of cattle occurring in the cycle. That this assumption differs markedly from reality is abundantly clear from any examination of the figures showing the condition of pastures and ranges. Year-to-year fluctuations of over 30 per cent took place in the 1930's. The effect of such violent changes on the amplitude and periodicity of the cycle could be great. The most striking example of such an effect is found in the drought years of 1934 and 1936. The rise in cattle numbers which had begun in 1928 would, in the absence of external disruptions, ordinarily have continued to about 1936. The severe drought of 1934 so reduced the carrying capacity of ranges that over four and a half million head were liquidated in the summer and fall of 1934. This was the greatest liquidation in our history. As a result, receipts of cattle at all stockyards reporting to the Department of Agriculture were, in 1934, over 50 per cent greater than in

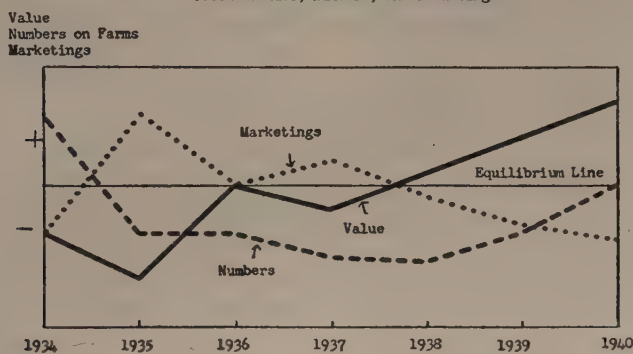
1933.²⁷ The value of cattle dropped sharply.

In the year 1935 weather conditions were much more nearly normal. Marketings dropped from their high in the preceding year of 19.7 million head to 15.0 million—a number very close to the average marketings over the preceding fifteen years. The value of cattle, as would be expected from the inverse correlation be-

marketings fell to 15.1 million head, cattle values returned approximately to their trend or "normal" line, and numbers of cattle on farms remained almost constant. In the subsequent twenty-four to thirty-six months animals were held back from market to rebuild drought-depleted herds, and cattle values rose.

The effects of the drought on cattle numbers, values, and marketings for the

Diagrammatic Representation of the Effects of the Droughts of the 1930's on Cattle Values, Numbers, and Marketings



The usual relationships between changes in cattle numbers, marketings, and value persisted throughout the droughts, although the continuity of the typical cycle was disrupted. A new and apparently normal cycle began in 1937, the beginning of a seven-year period of accumulation of cattle on farms.

FIG. 17

tween marketings and value, rose sharply to "normal."²⁸ The drought of 1936 caused further reactions similar to those in 1934, although the violence of changes occasioned by the second drought were very much smaller. Marketings again rose; cattle values and numbers on farms again fell. The return to normal of weather conditions made it unnecessary for farmers to continue liquidation because of the weather, and, as a consequence,

²⁷ *Agricultural Statistics, 1942* (Washington, D.C.: United States Department of Agriculture, 1942), p. 380.

²⁸ F. A. Pearson and W. I. Myers, "Prices," *Farm Economics*, No. 112, April, 1939, p. 2737.

years 1934-40 are represented diagrammatically in Figure 17. This diagram does not represent exact magnitudes, merely the direction and approximate relative magnitudes of the changes. It can be seen that marketings and values showed their usual inverse relationship and that accumulation and liquidation of cattle on farms accompanied high and low values, respectively. In these years it is almost certain that the primary cause of the changes was the drought with its forced liquidation of cattle inventories. In other periods it is more difficult, if not impossible, to assign a dominant role to any of the three series in dis-

rupting the self-perpetuating cyclical pattern. When the pressure of inadequate pastures and ranges was removed in 1937, the usual cyclical pattern once more began to emerge. Prices began to rise above "normal" and cattle began to be accumulated on farms at the expense of current marketings. Marketings began to rise significantly in 1940, three years after the accumulation had started. Accumulation on farms continued until 1944, a period of accumulation approximating the typical seven-year period as portrayed in the model.

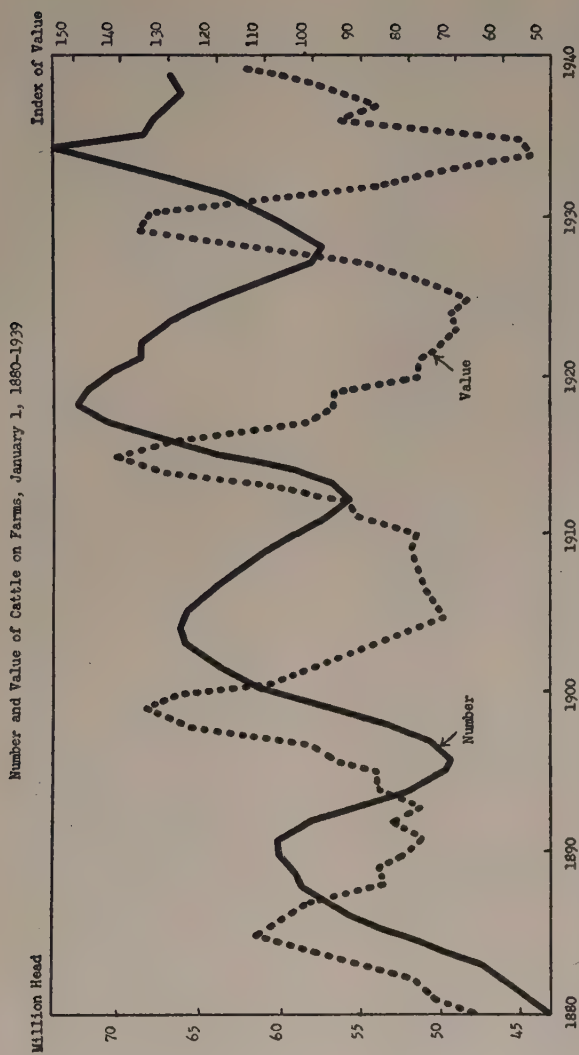
The weather, as an influence on the cattle cycle, seems to have disrupted the pattern only when pastures and ranges became unable to support the number that would have been supported in the absence of abnormal weather. The liquidation which results, through its effect on marketings and values, can alter temporarily the typical pattern. Unusually favorable weather, such as has been experienced in this country since 1940, seems to have merely a permissive influence, making possible fluctuations of greater than ordinary magnitude, but of the same type that would have occurred in times of normal grass and crop yields.

In regard to the effects of fluctuations in business conditions on the cattle cycle, the evidence is mostly negative. Short-term fluctuations in business activity and in the price level sometimes cause irregular fluctuations in the value (i.e., purchasing power) of cattle. Because of the length of the productive process involved in the cattle industry, the plans of farmers are somewhat inflexible—inflexible enough, the evidence shows, to prevent adjustment by farmers to these short-term fluctuations in business and prices. The series representing the value of cattle shows a marked cycle, but it is also characterized by the "saw-toothing"

which results from fluctuations counter to the cyclical pattern (Fig. 18). The series representing numbers of cattle on farms has almost no irregular fluctuations of this sort. Such irregular fluctuations are far more frequent for those classes of livestock, such as hogs and poultry, which have shorter gestation periods and which can be marketed in relatively short periods of time. Cattle producers cannot revise their production plans so frequently, and therefore the effect of brief irregular fluctuations in cattle values is not seen in the series representing cattle numbers.

The business cycle itself, whether defined by production, employment, or prices, seems to have had a relatively minor effect on the cattle cycle. The business cycle would logically affect the cattle cycle primarily through causing changes in the value of cattle. In the absence of multiple-correlation analysis, or some other statistical means for isolating the effect of single variables, it is impossible to define exactly the relative importance of the effect of cyclical swings in business activity and in the general price level on the value of cattle. It is possible, however, to see that the business cycle is not the primary or dominating influence on cattle values.

The first cyclical peak in cattle values occurred in 1885, the trough of what Leonard P. Ayres terms the "depression of 1884." The general price level was declining. The second peak occurred fifteen years later in 1899 during a moderate prosperity in which the index of business activity rose to 110 per cent of trend and the general price level was rising. The next peak, sixteen years later in 1915, occurred when business was in transition from the so-called "war depression" to the so-called "war prosperity." Prices rose sharply in the last months of the



The value series, although showing a definite cyclical pattern, was marked by irregular short-term fluctuations of minor amplitude. The series on cattle numbers showed almost no irregular extra-cyclical fluctuations.

FIG. 18

year. The next peak in cattle values occurred in 1929 during the boom of that year, which atypically occurred in the face of a declining general price level. This was the last peak in values to occur during the period under consideration. That these peaks could occur with such regularity—and with a periodicity not corresponding at all to the cycles in business activity and prices—and that the peaks occurred in both booms and depressions with rising, stable, and falling prices, is at least *prima facie* evidence that fluctuations in business activity and in the general price level do not provide the primary motivation for fluctuations in cattle values. The troughs in these values occurred under equally varied conditions. It is realized that such a lack of synchronization between the business and cattle cycles does not mean that the business cycles are without any influence. It does mean that other factors, presumably the interrelationships of mutual causality which are represented by the abstract model, are of more importance. The following paragraphs will attempt to examine in more detail the interrelationship of the two cycles—business and cattle.

It is commonly recognized that agricultural prices in general have more violent fluctuations than the general price level. This tendency exists for cattle prices as well. For a relatively recent example of such price movements, there is the depression of the 1930's. Cattle prices declined from an index (1910-14 = 100) of 174 in 1929 to an index of 67 in 1933, while the index of all commodities was falling from 141 to 95. In the recovery which terminated in 1937, cattle prices rose about 100 per cent, while the index of all commodity prices rose only about 30 per cent. In so far as this rela-

tionship is persistent, and in so far as the general price level is correlated with the business cycle, the value of cattle will rise and fall with the business cycle, *ceteris paribus*. That other things do not remain constant or equal has been amply demonstrated, however. The expansion and the contraction of cattle numbers and marketings continue. Fluctuations in business activity and the general price level will affect cattle values concomitantly with changes in numbers and marketings and will serve merely to modify the preponderant influences of the endogenous factors.

It can be said that a business depression will accentuate any decline in the value of cattle which may be occurring because of increased marketings and will dampen any rise in values which is accompanying decreased marketings. As an example of the former, there is the depression of 1929-34, in which the value of cattle dropped to an index of 55 in 1933 (1910-14 = 100), a level over ten points less than that of any previous trough in values. As an example of the latter influence, there is the peak in the cycle of cattle values which occurred in 1885. At this time the index rose to 112, twenty points less than any of the three subsequent peaks. In 1885 the index of business activity was about 10 per cent below its trend and prices were falling. Such crude observations do not, of course, "prove" the theory stated, but this evidence, superficial as it is, perhaps increases the confidence with which the deductive theory may be accepted. Examples of the accentuating and ameliorating effects of booms in business activity and of a rising general price level are harder to find because of the lack of any pronounced boom occurring simultaneously

with a period of rising prices *and* with either a peak or trough in cattle values.²⁹

Before passing on to a consideration of variations in hog numbers, an inspection of fluctuations in numbers of dairy cattle may serve to make clearer the causes of fluctuations in "other cattle." Even a casual inspection of the data shows the absence of any marked cyclical pattern in fluctuation in the number of dairy cattle on farms (Fig. 19). Yearly fluctuations of any kind have been of small amplitude, usually less than one million head in any twelve-month period. It will be recalled that the cycle in numbers of "other cattle" was explained in terms of the productive process involved—a process requiring a substantial time lag (two to four years) between a decision to increase production and the marketing of the products which resulted from that decision. Further, it was seen that a decision, motivated by "high" values, to increase production necessarily caused a decline in current marketings and a consequent further rise in values. The absence of a marked cycle in numbers of dairy cattle can be explained by an almost complete absence of these characteristics in the dairy-production process. A rise in the value of milk can be reflected almost immediately in a rise in production, with no necessity for increasing numbers or for decreasing mar-

ketings. The rise in production can, and for the most part does, come from increased feeding rather than from increased herds. Similarly, a decline in the value of milk can result almost immediately in a decline in production and an accompanying decline in marketings. Because of the lack of any self-reinforcing tendency toward cumulative over- and underproduction, milk production has been remarkably stable from year to year. During the decade of the 1930's per capita milk production varied within a range of less than 5 per cent.³⁰ Because of the flexibility in the production process, and because of the possibility of quickly adjusting production to price, this stability persisted in spite of the worst droughts in history. In explaining this remarkable stability, Vial, Myers, and Pearson state:

During the short crops of the drought years farmers liquidated hogs, poultry, and cattle. This liquidation temporarily increased the volume of meat on retail counters, which forced prices down. In striking contrast the poor pastures and short feed supplies curtailed the production of milk and caused its price to rise. With these high prices of dairy products relative to meat animals, milk cows received more than their usual proportion of pasture, hay, and grain. Consequently, milk production was curtailed relatively little compared with the decline in the production of feed or other livestock products.³¹

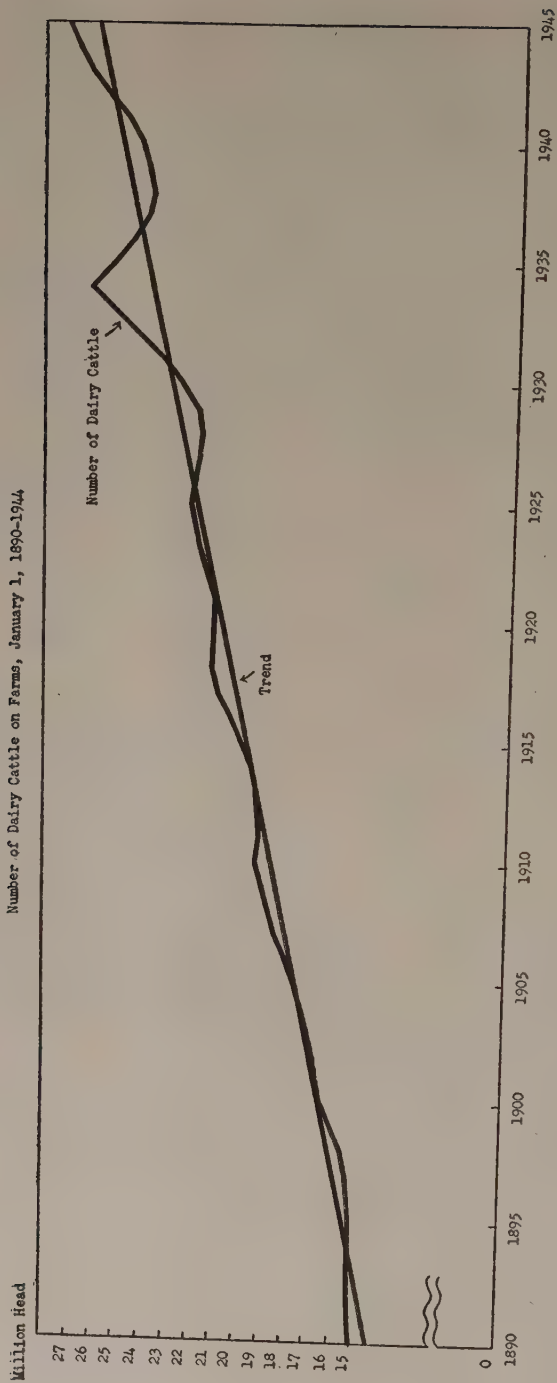
In this quotation lies the explanation of the absence of cyclical fluctuations in dairy-cattle numbers. A forced reduction in production need not, and did not, lead perversely to increased marketings and lower prices but rather to decreased marketings and higher prices. As a re-

²⁹ It seems necessary to state the obvious before leaving this section of the study. The explanation of the cattle cycle which has been presented is a highly simplified statement of a system of interrelationships. The effects of many variables have not been considered even qualitatively, and, of course, no quantitative conclusions have been reached. The definition of this cycle in terms of a system of the many interrelated variables which comprise it would be a major task in econometrics. The type of study which would be necessary is that found in Haavelmo's study of pig production in Denmark (Trygve Haavelmo, *A Dynamic Study of Pig Production in Denmark* [Ejnar Munksgaard, 1939]).

³⁰ E. E. Vial, W. I. Myers, and F. A. Pearson, "Milk in War and Peace," *Farm Economics*, No. 151, August, 1946, p. 3850.

³¹ *Ibid.*, p. 3852.

Number of Dairy Cattle on Farms, January 1, 1890-1944



Yearly fluctuations were of relatively small magnitude, no marked cycle being evident.

FIG. 19

sult, the initial decline in production led to higher prices and a stimulus to higher production. For beef cattle, among other classes of livestock, the initial decline in production led to lower prices and to a stimulus to further reductions in production.

In the preceding pages it was shown that fluctuations in numbers of "other cattle" on farms accounted for the major cycle in the index of animal units on farms, and an attempt was made to explain the nature and causes of the cattle cycle. In the following pages an attempt will be made to explain fluctuations in the index of animal units due to causes other than the rise and fall of the major cycle.

FLUCTUATIONS IN THE HOG POPULATION

In order to eliminate the fluctuations in the index of all animal units which were the result of the cyclical pattern in numbers of "other cattle," a smooth fourteen- to sixteen-year cycle³² was fitted free hand to this index (Fig. 20). Then, the index as a percentage of this cycle was computed. These residuals, when plotted, revealed a minor irregular cyclical pattern, the cycles being from three to six years long. Because of the method of fitting the smooth cycle from which these residuals were derived, the residuals represent any minor cyclical and random fluctuations remaining after the effects of the major cycle *and* of trend were eliminated. Because of the relatively great quantitative importance of hogs among those classes of livestock whose influence on fluctuations in the index had not been eliminated, it was not difficult to predict that fluctuations in hog numbers would account for almost all the residual fluctuation in the index. Figure

21 reveals the close correspondence between the residuals and hog numbers expressed as a percentage of trend.

Although the cyclical pattern in hog numbers is not so pronounced or regular as in the case of "other cattle," what appears to be a three- to six-year cycle does seem to exist. The same interrelationships between numbers on farms, values, and marketings which existed for "other cattle" exist also for hogs—that is, a rise in the value of hogs will lead to an accumulation of hogs on farms and a reduction in current marketings *ceteris paribus*. This reduction in marketings will, in turn, lead to a further rise in values and a further increase in numbers on farms.

As in the case of beef cattle, there is a time lag between the decision to increase production and the marketing of the product resulting from that decision. For hogs the time lag is much shorter, however, being about one year in length. As was true for the cattle cycle (as illustrated in the abstract model), the length of the complete cycle in hog numbers could be expected to be, in the absence of impinging exogenous influences, about four times the length of the period required for gestation and the readying of the young animals for market. This would lead to a four-year cycle in hog numbers, the result of alternating two-year expansions and contractions. That the actual cycle does not conform very closely to the expectations induced by a consideration of the inherently cyclical production process alone is due to the relatively great sensitivity of hog production, as compared with beef production, to exogenous influences. Hog production more frequently than beef enterprises is carried on in conjunction with other operations which can, under propitious circumstances, be expanded to utilize resources left idle by a reduction in the

³² Because of the influence of the drought, the cycle during the 1930's was about eleven years long.

Cattle Cycle Fitted to the Index of All Animal Units on Farms, 1890-1944

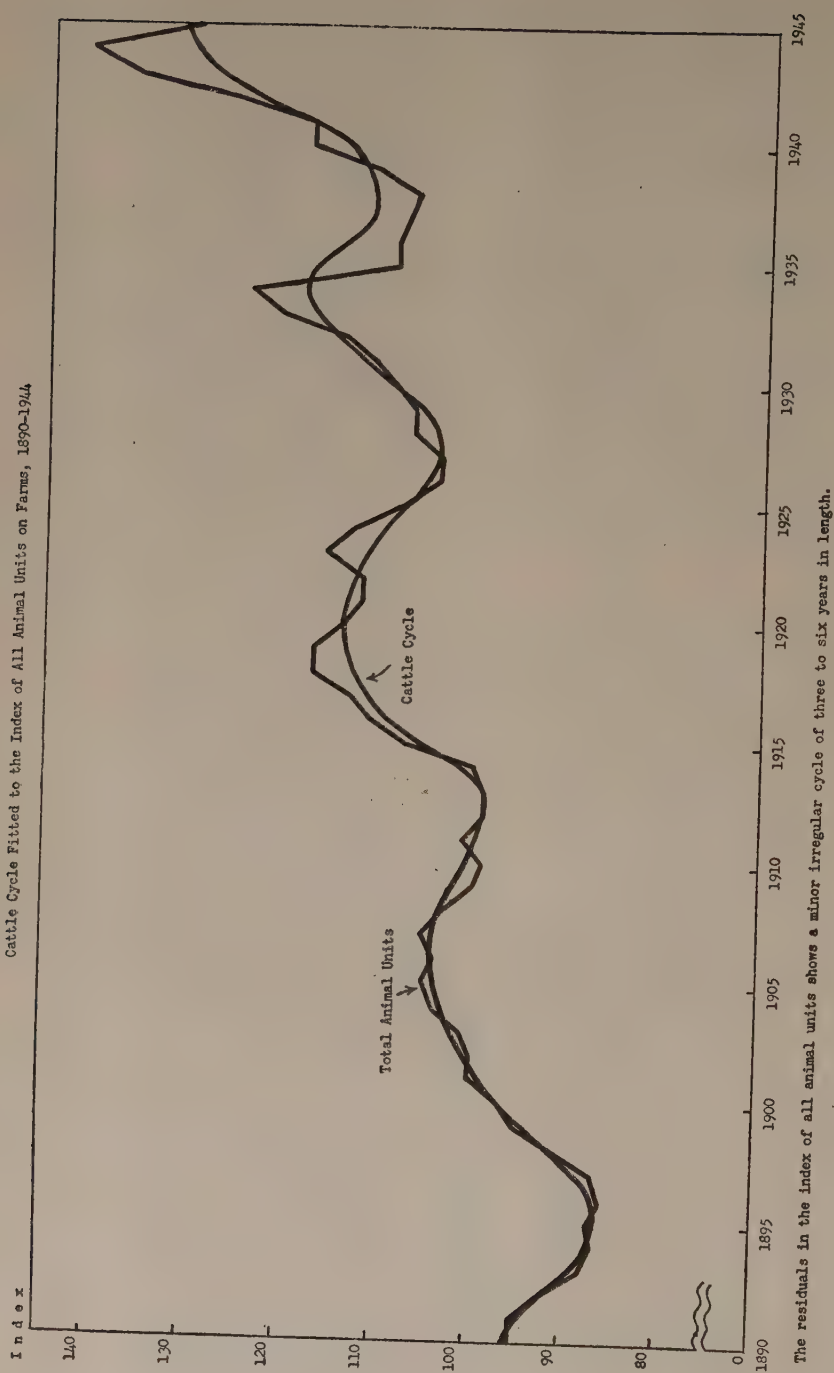
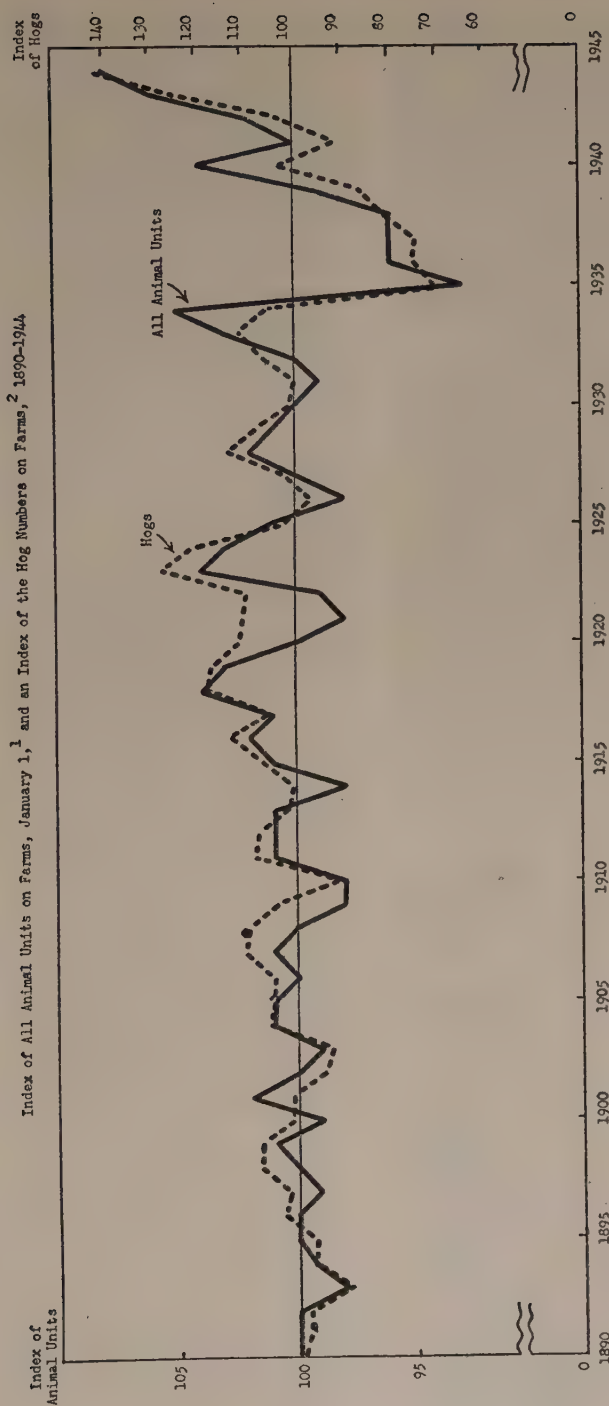


FIG. 20



¹Expressed as a per cent of the major cycle and of trend.

²Expressed as a per cent of trend.

Fluctuations in numbers of hogs accounted for most of the residual fluctuations in the index of all animal units.

FIG. 21

scope of the livestock program. Similarly, resources can more easily be diverted for an expansion of the hog enterprise. Because of this frequently present flexibility in the use of resources and because of the relative speed with which production can be expanded and terminated, hog numbers are increased and decreased significantly in response to types of economic stimuli which frequently elicit no reaction from beef producers.

It is not within the scope of this study to undertake a comprehensive analysis of all these external factors which affect the value of hogs and, in this way, the number on farms. An extensive literature on this subject has developed³³ which has attempted to find statistical evidence as to the primary determinants of hog prices. A pioneer in this field, Sewall Wright, constructs what he terms a "central system of relations," including in it those variables with the most important causal influence on hog breeding (or production). In regard to this system Wright comes to the following conclusions:

1. Among the corn variables, the price has in general the closest correlations with the hog variables and is thus the best one to take as representative of the influence of corn on hogs. . . .

2. . . . Summer weight is a close indicator of the amount of breeding in the same years.

3. The summer weight is determined 60 per

³³ Among the basic works are the following: Sewall Wright, *Corn and Hog Correlations* (United States Department of Agriculture Bull. 1300 [Washington, D.C., 1925]); G. C. Haas and M. Ezekiel, *Factors Affecting the Price of Hogs* (United States Department of Agriculture Bull. 1440 [Washington D.C., 1926]); K. Bjorka, *Some Statistical Characterizations of the Hog Market* (Agricultural Experiment Station, Iowa State College of Agricultural and Mechanic Arts Research Bull. 102 [Ames, Iowa, May, 1927]); F. F. Eliot, *Adjusting Hog Production to Market Demand* (University of Illinois, Agricultural Experiment Station Bull. 293 [Urbana, Ill., June, 1927]); and O. V. Wells, *Farmers' Response to Price in Hog Production and Marketing* (United States Department of Agriculture Technical Bull. 359 [Washington, D.C., April, 1933]).

cent by the preceding winter price of hogs (positive) combined with the price of corn (negative) at the same time, and this percentage determination is higher than that resulting from any combination of variables not including these two factors. *This result was interpreted as meaning that the amount of breeding is determined primarily by profits derived from hog raising in the preceding year.*

4. The winter price of hogs is determined "to the greatest extent" by the preceding summer weight and the preceding prices of corn.

5. Summer hog prices are influenced primarily by four factors: the breeding of the two preceding years (negative) and the corn prices of the same and preceding falls (positive).

6. Thus, a system of corn-hog relations can be built around the interrelations between breeding, the winter and summer hog prices, and corn prices.³⁴

This system differs from that existing for cattle in that the price of feed, represented for practical purposes by corn, is a fundamental determinant of the profitability of the productive enterprise. Corn as a factor of production is devoted to hog production in greater or less quantities according to the relationship of its price to the price of its products, pork and lard. Since corn is both storable and transportable and can be used in other livestock enterprises, the always-present alternative of use and/or sale and/or purchase are available to the hog producer. The decision which is made will, of course, influence hog production, hog prices, and the future hog-corn price ratios. In the case of beef cattle the basic feedstuff (grass) can only to a very limited extent be bought, sold, or used for purposes other than the pasturing of cattle. The cost of this feedstuff is usually found in the form of *fixed* costs represented by investment in land. Fluctuations in the profitability of the beef operation can reasonably be assigned, therefore, to fluctuations in the value of beef rather than jointly to fluctuations in the

³⁴ *Op. cit.*, pp. 44-45. (Italics mine.)

cost of the feed and of the livestock product.

The profitability of both hog and beef operations are obviously dependent on the relationship between *all* costs and *all* revenues. In beef production a very high percentage of the costs is fixed and "unvarying"³⁵ and therefore need not be considered in analyzing fluctuations in profits and the responses of producers. In hog production, feed costs, a large proportion of total costs, vary widely from year to year and must therefore be considered in this analysis. Since corn is by far the most important hog feed and is representative in its price fluctuations of most other hog feeds, the analysis will be restricted to a consideration of causes of fluctuations in corn prices.

On this problem, too, a large literature exists. Perhaps the best-documented work is again that of Wright. His conclusions, though reached some twenty years ago, probably apply with equal validity to current fluctuations, excepting, of course, the effect of a very much increased governmental influence. Regarding this influence few generalizations can safely be made. Realizing that governmental action can be dominant, it will nevertheless be helpful to see the nature of price fluctuations in the absence of this influence. In general, Wright reaches the following conclusions:³⁶

³⁵ The unusual term "unvarying" seems useful here. While it is true that a large proportion of the costs of beef production are "fixed" in the technical economic sense, it seems more helpful in understanding the smoothness of the cattle cycle to point out that a very large proportion of costs per unit does not vary markedly from year to year. This is not true, of course, of cattle-feeding operations in the Corn Belt and elsewhere, but such operations are not varied according to the absolute value of cattle but according to the spreads between the value of unfinished and finished cattle.

³⁶ For further confirmation of these conclusions see chap. ii above.

1. The size of the corn crop is determined completely by the acreage and yield. Of the two factors, variations in yield have had a very much more important determining influence than variations in acreage.

2. The acreage planted in a given year has no relation to the preceding crops. There is a very slight positive correlation between acreages in successive years and a slight negative correlation between acreages and the price for the preceding crops.³⁷ There is also a very low positive correlation between acreage and pork production in the preceding years.³⁸

3. Fluctuations in yield are "undoubtedly due in the main to the weather."

4. In summary of the preceding three points, it can be said that the corn crop is determined "*not more than 10 per cent* by the hog situation and perhaps 4 per cent by the preceding corn crop. Practically, the corn crop can be treated as an independent variable in its relation to the hog situation of the same and later years."³⁹

In regard to Point 4, it is probable that Wright understates rather than overstates the influence of hog production and acreage in the preceding years. The correlation coefficients which are used to support his contention of influence are probably not significantly different from zero. However, even if one accepts these coefficients as significant, the overwhelmingly dominant influence on the size of the crop is the weather.

Interest is given to the explanation of the determinants of the size of the corn crop only because the size of the crop influences its price and hence the profitability of hog production. Several economists have found that the size of the crop is the most important determinant of its price. Warren and Pearson stated that the gross correlation coefficient be-

³⁷ The gross correlation coefficients are $+0.36$ and -0.22 , respectively, coefficients of very doubtful significance.

³⁸ The gross coefficients are $+0.27$ and $+0.17$ for summer and winter, respectively. It is doubtful that these are significant, especially in view of the implied negative correlation with hog prices.

³⁹ *Op. cit.*, pp. 13, 21, and 22.

tween the production of corn and a deflated December 1 farm price for the period 1879-1913 was $-.839 \pm .032$.⁴⁰ Schultz found an adjusted multiple-correlation coefficient of .7076 between a deflated price series for corn, the dependent variable, and corn production and "time," the independent variables for the period 1915-29.⁴¹ The preponderant influence on price, according to these authorities, is the size of the crop; and the size of the crop, it been shown, fluctuates from year to year almost exclusively because of changes in the weather.

In regard to possible minor influences on price, only fluctuations in the number of animals on farms seems to have been of any significance. Schultz found that a significant percentage of variance in a series representing a deflated farm price of corn was attributable to fluctuations in the livestock population.⁴² The influence of such fluctuations in animal numbers has probably become greater through the years as corn requirements per animal unit have increased. An explanation of this secular change in the demand for corn is found in Shepherd's *The Secular Movement of Corn Prices*.⁴³ Shepherd forwards the thesis that the tendency to market steers and heifers as baby beef rather than as four- or five-year-olds

caused the increase in the demand for corn per animal unit. The influence of the livestock population is significant but of minor importance when compared with that of the size of the crop.

In regard to business conditions Schultz concluded that they were without significant effect either on the quantity of corn demanded or upon its price.⁴⁴ Nor, it is believed, has anyone ever found evidence to indicate that business conditions importantly affect the livestock population and in this way partially determine corn prices. No extra-agricultural influence seems significant when compared with weather-induced fluctuations in the size of the crop.

The preceding discussion of corn prices is important for an understanding of the relative irregularity in the hog cycle. The same regular inherently cyclical pattern exists for hog production that existed for beef production. But in the case of hogs this pattern is subject to the disturbing influence of changes in the price of feed—which is to say, for practical purposes, the price of corn. In so far as fluctuations in this price affect the profitability of hog production, they will impinge upon the regular cyclical pattern in hog numbers and cause the irregularities which have been noted. Because each year's temperature and rainfall are believed to be independent of weather conditions in preceding years, it can be seen that changes in the weather will have a random influence on the hog cycle, causing irregularities in the regular four-year cycle rather than inducing another cyclical pattern. A short corn crop with its accompanying "high" price would tend to dampen the upswing in hog numbers or to cause a reversal, and it would tend to accentuate the severity

⁴⁰ G. W. Warren and F. A. Pearson, *Interrelationships of Supply and Price* (Cornell University Agricultural Experiment Station Bull. 466 [Ithaca, N.Y., March, 1928]), p. 119.

⁴¹ Henry Schultz, *The Theory and Measurement of Demand* (Chicago: University of Chicago Press, 1938), p. 271. The years 1917-21 were omitted. The unadjusted multiple-correlation coefficient would be approximately .95. The adjusted coefficients for the periods 1879-95 and 1896-1914 were .8717 and .9779, respectively.

⁴² *Ibid.*, p. 274.

⁴³ G. S. Shepherd, *The Secular Movement of Corn Prices* (Iowa State College Agricultural Experiment Station Research Bull. 140 [Ames, Iowa, 1931]), p. 197.

⁴⁴ *Op. cit.*, p. 279.

of the liquidation phase of the cycle. It is beyond the scope of this study to document these hypothetical examples with actual instances, because of the complex and prolonged statistical computations necessary to isolate the effect of the single variable—the price of corn. It is possible to posit with a fair degree of assurance, however, that the price of corn after the drought of 1934 contributed greatly to the extraordinarily severe liquidation of hog numbers which occurred at that time. Bumper crops such as we have had in the early 1940's made possible the unusually prolonged and large expansion in hog numbers which took place in 1942, 1943, and 1944, although government price regulations undoubtedly made the increases greater than would have occurred in the absence of price controls.⁴⁵

Just as the effect of the cattle cycle on the index of animal units on farms was eliminated by expressing this index as a percentage of a smooth fourteen- to sixteen-year cycle, so the effect of fluctuations in hog numbers was eliminated by expressing the residuals of the index from the cattle cycle as a percentage of a fairly regular four- to five-year cycle in hog numbers weighted appropriately. The resultant series expresses the yearly fluctuations⁴⁶ in the index not attributable to the cyclical elements in cattle and in hogs. These residual fluctuations are of relatively small magnitude as would be expected when it is realized that most of the effect of yearly fluctuations in the numbers of hogs and of "other cattle" has been eliminated and that only the effect of fluctuations in numbers of milch cows, chickens, and sheep remain (Fig. 22).

⁴⁵ Crickman, *op. cit.*, p. 27.

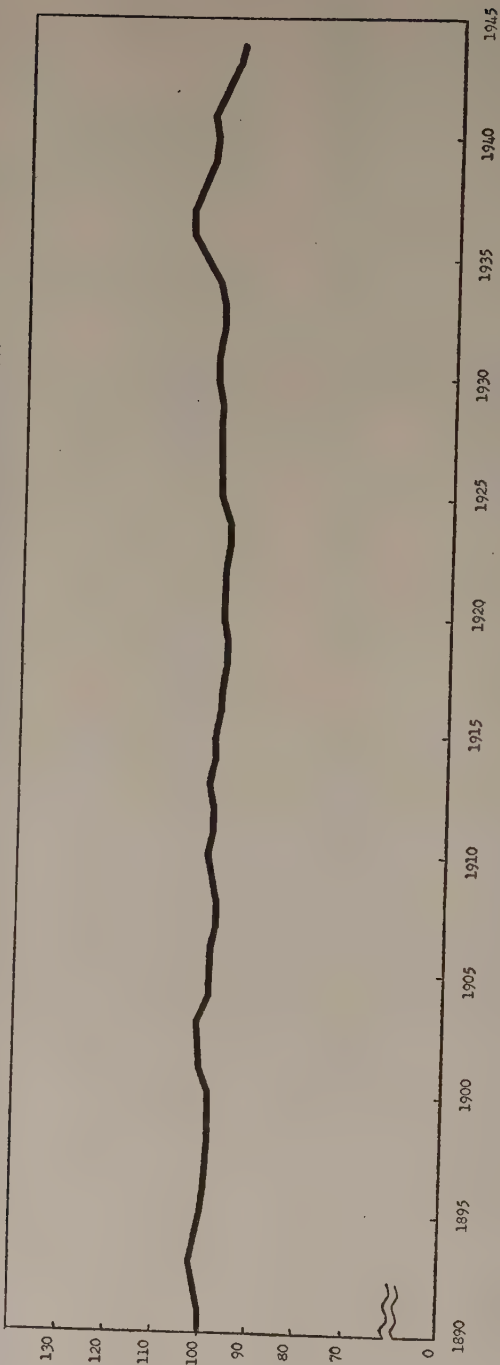
⁴⁶ The effect of trend is eliminated; trend will be considered later.

FLUCTUATIONS IN NUMBERS OF MILK COWS ON FARMS

It has already been shown that the dairy-production process does not have those cycle-generating characteristics found in beef and hog production. Numbers of milk cows are also less subject than hogs to random fluctuations because of weather-induced changes in the price of feeds. There are two main reasons for this. First, the range of feedstuffs which can be efficiently utilized by dairy cows is much greater than that which can be utilized by hogs. Hogs receive most of their feed in the form of corn, for which there is no suitable substitute available in this country in large quantities. The hog's simple stomach prevents the substitution of roughage for concentrates or of oats for corn, which the cow's compound stomach makes possible. Because the cow is not so dependent on a single feed, particular crop failures do not so seriously affect the dairy-cow population as do fluctuations in the corn crop the number of hogs on farms. Second, production of dairy cattle can be varied within a fairly wide range in response to changing feed prices without either increasing or liquidating herds. As feed increases in price, it is possible for the dairyman to increase its marginal productivity by decreasing the rate of feeding. This is also possible to some extent for the hog producer, although the range of possible variation is less. Another factor which makes it economically rational for dairymen more than hog producers to respond to fluctuations in the price of feed by varying rates of feeding rather than by varying the number of animals being fed is the relative costs involved in liquidating and rebuilding breeding herds.

When it is realized that fixed costs of

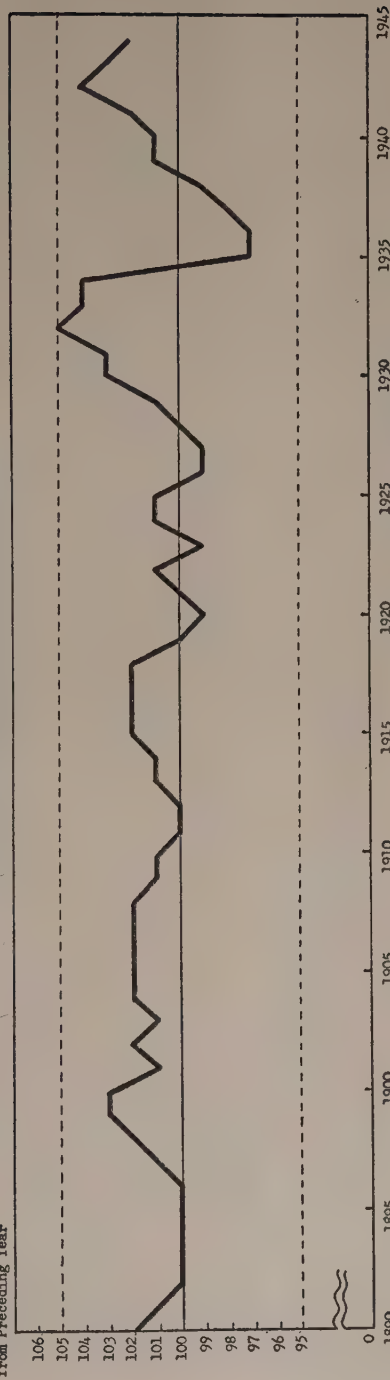
Index of
Animal Units
Effect of Trend and of Cyclical Fluctuations in Numbers of Hogs and "Other Cattle," 1890-1944



The residual fluctuations are of relatively minor importance when compared with fluctuations in numbers of hogs and "other cattle."

FIG. 22

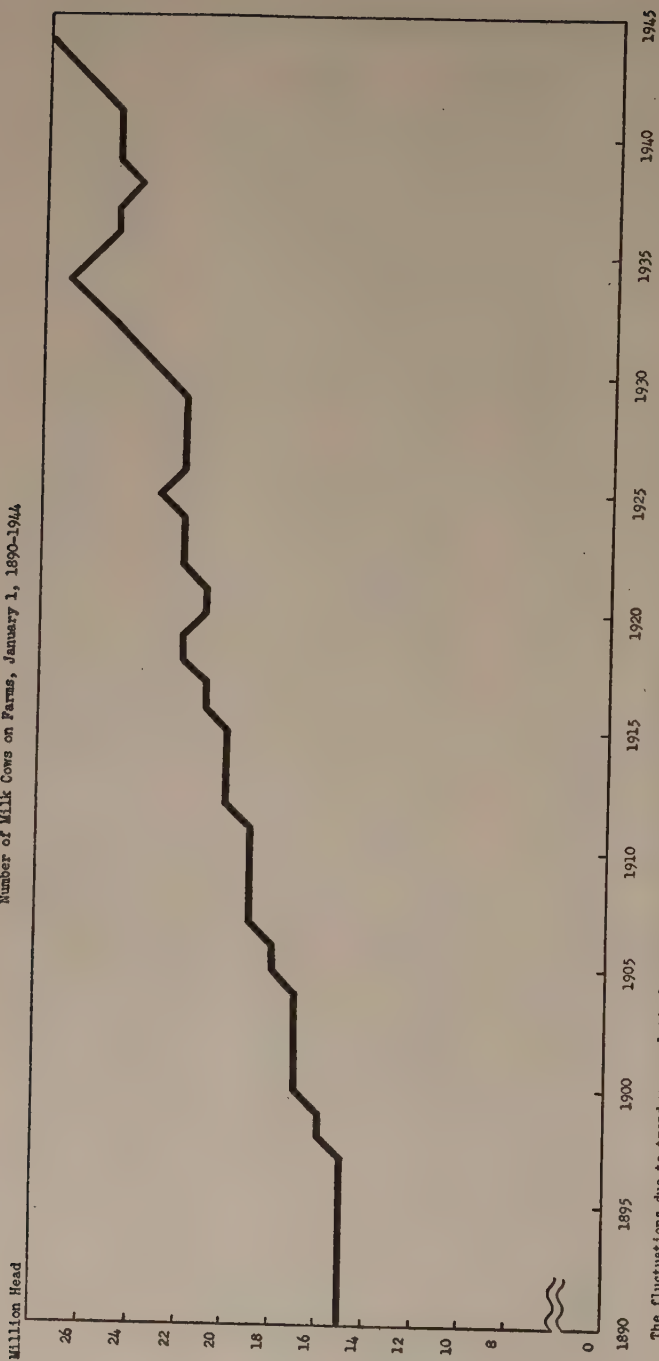
Number of Milk Cows on Farms, January 1
(Expressed as a Per Cent of Preceding Year), 1890-1944



Fluctuations typically were small, being in almost all cases less than 3 per cent per year.

FIG. 23

Number of Milk Cows on Farms, January 1, 1890-1944



The fluctuations due to trend were relatively important compared to those ascribable to cyclical or random influences.

FIG. 24

most dairy enterprises are relatively high, even on an animal-unit basis, when compared with hog enterprises, it can be seen that many short-term fluctuations in the cost of feed will have less effect on dairy production, and a fortiori on numbers of milk cows, than they will have on hog production and on hog numbers. This absence of cyclical characteristics and relative immunity to the effects of the random fluctuations in the price of feed are reflected in the very small yearly fluctuations in dairy cows (Fig. 23). From 1890 to 1919 there was a gradual and remarkably steady increase in numbers of dairy cows. In no year did the population of these animals fall below that in the preceding year, and in only two years was the increase over the preceding year greater than 2 per cent (Fig. 24). From 1919 to 1929 the fluctuations continued small, being less than 2 per cent in all years. In the last fifteen years of the period (1930-44) the fluctuations became more violent, the greatest percentage occurring from January, 1931, to January, 1932—an expansion of 5 per cent. The greatest liquidation—3 per cent—occurred after the drought of 1934. Although these fluctuations are great compared to those in earlier periods, they are, of course, very small when compared to fluctuations in hog and “other cattle” numbers. Numbers of “other cattle” changed by as much as 9 per cent in a single year, and changes of 6 per cent were rather frequent. Hog numbers declined by over 33 per cent in 1934, and expansions of over 15 per cent were not uncommon. The relative importance of trend and relative unimportance of cyclical and random fluctuations in numbers of dairy cows can be seen in Figure 24.⁴⁷

⁴⁷ The trend in this series will be discussed in more detail later.

FLUCTUATIONS IN SHEEP AND POULTRY NUMBERS

The classes of livestock remaining to be considered, sheep and poultry, are only of minor importance in causing fluctuations in the index of all animal units on farms. The relative insignificance of these classes of animals derives, not from the fact that they do not have proportionately large yearly fluctuations in numbers, but from their minor weight in the index of all animal units. The relative weights of the various classes of livestock in this index for the years 1890 and 1944 are shown in Table 8.

TABLE 8
RELATIVE WEIGHTS OF THE VARIOUS CLASSES
OF LIVESTOCK, 1890 AND 1944

Livestock	1890	1944
“Other cattle”.....	45	36
Milk cows.....	21	26
Hogs.....	20	23
Chickens.....	7	8-9
Sheep.....	7	6
	100	99-100

Sheep and chickens together constituted less than one-sixth of the total index at both the beginning and the end of the period under consideration. Neither constituted as much as 10 per cent.⁴⁸ Even though the fluctuations in numbers of sheep on farms occasionally were as much as 5 per cent in a single year, their effect on the total index was negligible. Fluctuations in numbers of chickens on farms (or produced) were more violent, occasionally amounting to as much as 15 per cent in a single year; but even these more violent fluctuations could not cause the index of all animal units to change

⁴⁸ If the number of chickens produced in a year, rather than the number on farms January 1, were considered, chickens would constitute about 10 per cent of the index in 1890 and about 12 per cent in 1944.

more than 1 or 2 per cent. Nevertheless, for the sake of completeness, a brief inquiry into the nature and causes of fluctuations in sheep and chicken numbers will be undertaken.

If sheep did not produce two products of economic importance (meat and wool) the nature and causes of fluctuations in the number of sheep on farms could be expected to be much like those for numbers of beef cattle. Sheep, like beef cattle, depend for their feed primarily on pastures and ranges—a fact which means that feed costs are not variable to any significant extent in the short run. The profitability of sheep production, like that of beef production, is therefore dependent in the short run primarily upon the value of the products of the enterprise. Sheep, like beef cattle and unlike hogs, do not evidence many random fluctuations in numbers which can be attributed to fluctuations in the price of feed. Feed probably is an important factor in causing fluctuations only when severe drought not only cuts production of meat and wool but so reduces the carrying capacity of pastures and ranges that liquidation is forced on sheep producers. The sheep-production process is inherently cyclical for the same reason that hog and beef production are cyclical.

Forgetting for the moment the peculiar problems caused by the existence of a secondary but still important product, wool, it can be seen that a rise in the value of mutton will cause an incipient accumulation of sheep on farms with the now familiar diminution in the number of sheep sent to market and the accompanying further rise in their value. If it were not for the existence of wool, the sheep cycle would be in its nature, though not in its duration and amplitude, like the beef cycle. The cycle could

be expected to be about eight years long—that is, a period four times the period of gestation, plus the average age at which sheep are marketed. Wool complicates the nature of the sheep cycle, while hides were without independent influence on the cycle in numbers of beef cattle. There are two reasons for this difference in influence. First, and more obvious, is the much greater proportionate value of wool in the sheep enterprise as compared to hides in the production of beef animals.⁴⁹ Second, the marketings of wool do not react in what may be described as the “perverse” manner of mutton and beef (and hides) to changes in value; that is, a rise in the value of wool does not lead to a temporary decline in its marketings, nor does a fall in its value lead to increased marketings. In the following paragraph the influence of wool on the cycle will be considered.

Let it be assumed that an equilibrium position is disturbed by some influence—say, an increase in demand—which raises the value of lamb while not affecting the value of wool. This rise in the value of lamb typically has caused farmers to increase numbers of sheep on farms, with a consequent diminution in marketings and a further increase in value. The decision to accumulate sheep on farms affects wool differently. The accumulation initially has little effect on either its marketings or its value. About a year after the accumulation starts, however, the increased number on farms will increase the clip and cause a fall in the value of each unit of wool, *ceteris paribus*.

Since the decision to accumulate or liquidate animals depends upon the profitability of the sheep enterprise as a whole, changes in the value of wool as

⁴⁹ Income from wool normally constitutes about 40 per cent of all income derived from sheep enterprises in this country.

well as mutton will be of importance in affecting numbers on farms. The elasticity of the demand for wool will, of course, determine whether the increased quantity coming on the market will yield a greater or less total revenue to the sheep producers. In the following discussion it will be assumed that the elasticity is less than 1. Thus the increase in the marketings of wool will cause a decline in total revenue.⁵⁰

This decline in the value of and revenue from wool which accompanies any increase in numbers on farms will partially or completely offset the increase in the value of sheep which is caused by the rise in the value of lamb. In the absence of constant and statistically defined demand curves for wool and lamb, it is impossible to quantify the changes in value per unit or in revenue that will be caused by the changes in supply. It is possible, however, to be sure that the decrease in the value of wool will cause the value of sheep to start declining and to fall below the "equilibrium" level sooner than would be the case in the absence of wool. If wool were not present as an economic factor, the value of sheep would be expected to stop rising and to start declining about two years after the initial decision to accumulate sheep; the value of sheep would be expected to fall below the equilibrium level about four years after the initial decision. The value reactions of wool and the assumed elasticity of demand insure that the value of sheep will start declining in less than two years and that it will fall below the equilibrium level in less than four.

In the subsequent phases of the cycle the dampening effect of wool would be equally apparent; that is, liquidation of

sheep will cause, after a lag of about a year, the value of wool to rise, partially or wholly offsetting the decline in the value of mutton. Thus, the amplitude and duration of the liquidation phase, too, is lessened. This system of interrelationships is no different when the initial disturbance is a change in the value of wool rather than in the value of mutton. The accumulation of sheep on farms, whether the causal factor is an increased value of wool or of mutton, will cause the value of mutton to rise and that of wool to fall and will result in a dampened and shortened "eight-year" cycle.

Although the sheep cycle is relatively immune to the influences of weather-induced fluctuations in the price of feed, it is subject to irregularities because of the many extra-national and extra-agricultural influences on the price of wool. It is obvious that wool, of which a major proportion of this country's supplies are imported, is subject to numerous value fluctuations attributable to forces other than changes in production in the United States. The unimportance of this point for this study makes elaboration unnecessary. It is enough to say that many foreign and domestic climatic, economic, and political factors can affect the value of wool, and hence of sheep production, and alter the regularity of the cyclical pattern. Evidence of the cycle and of its irregularities is found in Figure 25.

Fluctuations in chicken numbers will receive even briefer consideration. Chickens are valued primarily for their eggs rather than for their carcasses, just as milk cows are valued primarily for their milk rather than for their beef. Egg production, like milk production, responds rapidly to changes in value in a way which finds increased production associated after only a brief time lag with increased values and decreased pro-

⁵⁰ If $\eta > 1$, total revenue would rise and the effects on the cycle would be the reverse of those discussed above.

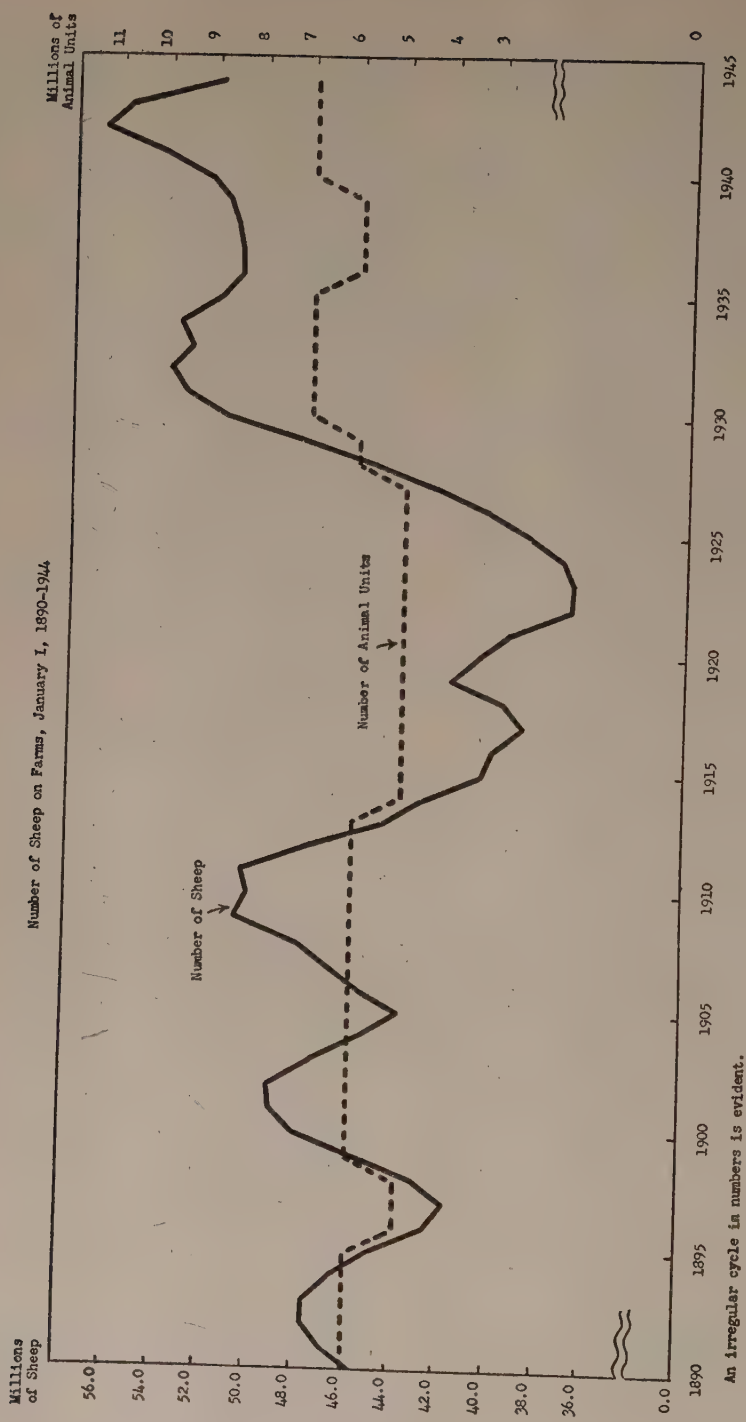


FIG. 25

duction with decreased values. Since egg production per hen cannot be varied so widely as milk production per cow by changing the rate of feeding, these responses in egg production can be effected for the most part only by increasing or decreasing the number of chickens on

pronounced upward trend that is apparent.⁵¹ The contribution of the various classes of livestock to this upward trend is presented graphically in Figure 27. The trend line of all animal units (excluding horses and mules) on farms was 68.4 million animal units in 1890 and

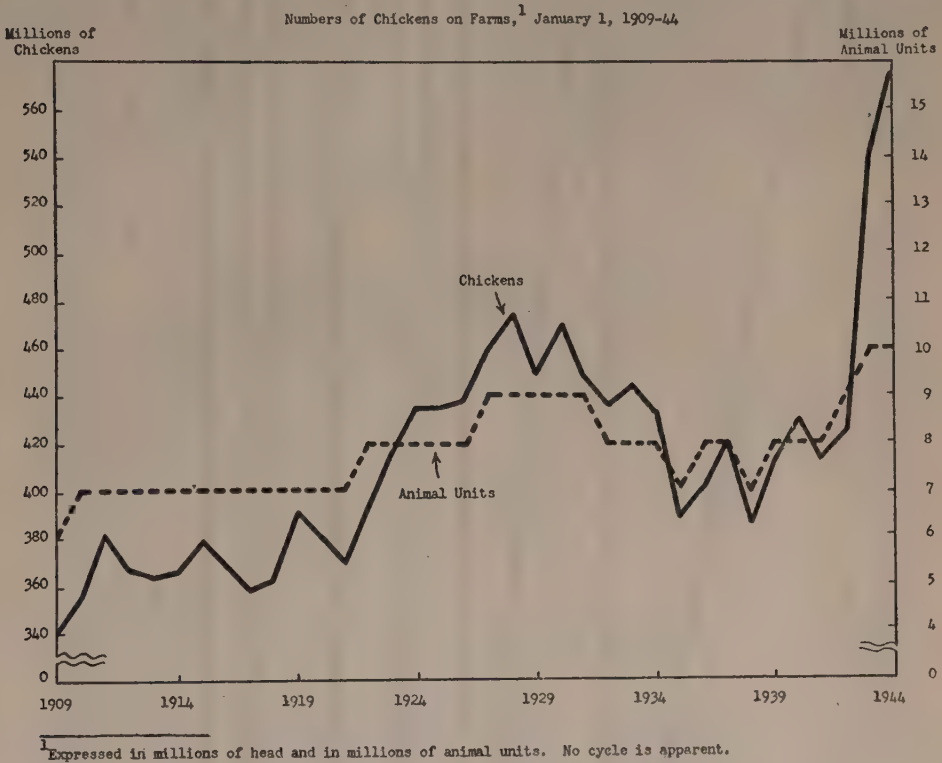


FIG. 26

farms. If monthly data were available, it is probable that some sort of cycle would come to light. The brevity of the gestation period prevents the cycle's being apparent on the basis of observation of an annual series (Fig. 26).

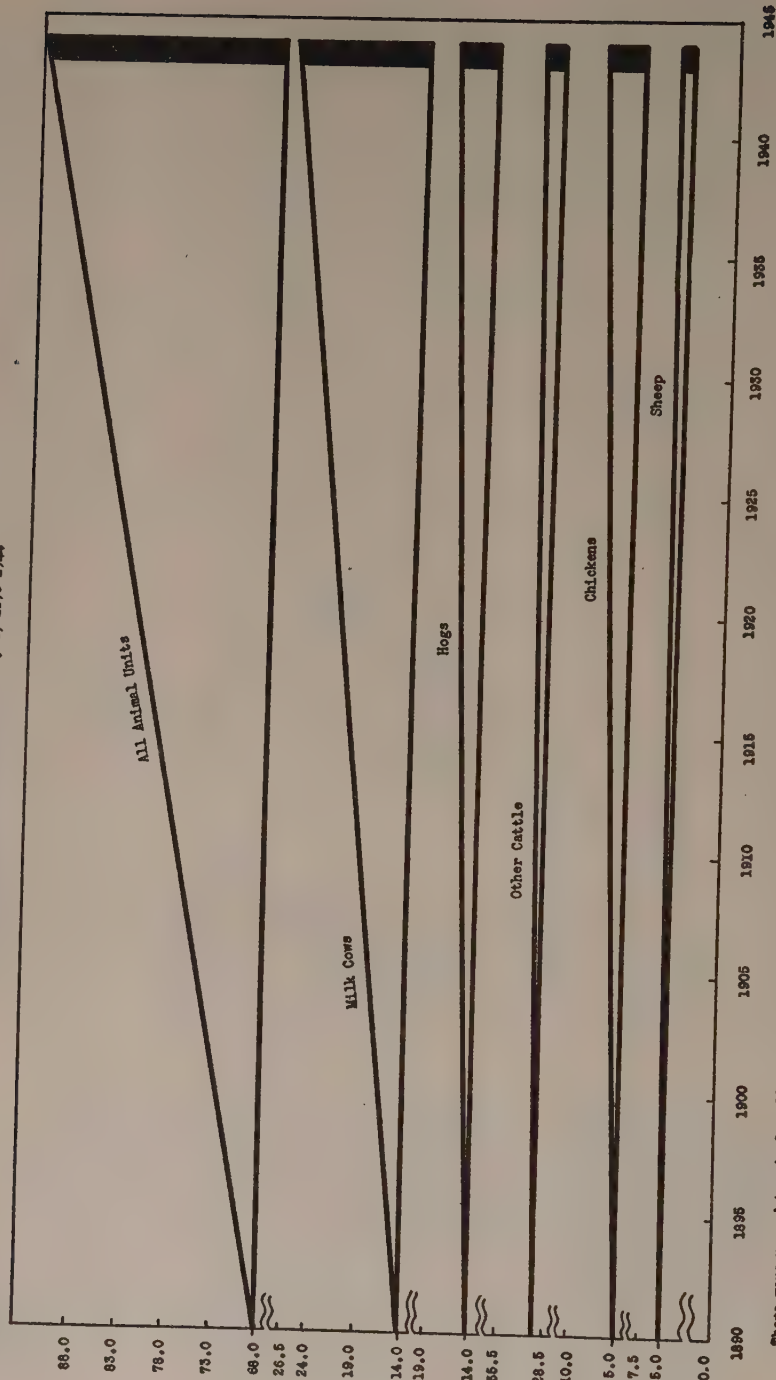
TRENDS IN THE NUMBERS OF ANIMAL UNITS ON FARMS

To complete this study of fluctuations in the index of all animal units on farms, it will be necessary to discuss the rather

92.9 million units in 1944. Of this increase of 24.5 million animal units, over half was due to the trend in numbers of milk cows. The secular increases in the various classes of livestock, expressed both in animal units and as a percentage of the increase in all animal units, are found in Table 9. The influence of the trend in numbers of dairy cows is more

⁵¹ A fitted linear trend line to the index for the period 1890-1944 has a positive slope of 0.45 points per year.

Trends of Various Classes of Livestock and of All Animal Units on Farms
(Excluding Horses and Mules) January 1, 1890-1944



There were upward trends for all classes of livestock, by far the most important of which was the trend in milk cows.

FIG. 27

than three times as important quantitatively as that of the trend for any other class of livestock and is more important than the trends in all other classes of livestock considered together. The importance of this secular trend in the number of all animal units was of slight significance, when compared to the effect of cyclical and random fluctuations, in causing yearly changes in the number of animal units on farms. The average yearly fluctuations in all animal units was 2.09 million, and, of this number, only 0.45 million could be attributed to secular trend.

SUMMARY

The preceding discussion of fluctuations in the number of animal units on farms seems to warrant making the following conclusions:

1. The decision to increase or to decrease production of livestock products seems to be most importantly affected by the expectations of the profitability of the enterprise, and these expectations seem to have been based upon a projection into the future of those livestock-feed price ratios which have existed in the recent past.

2. For certain classes of livestock—namely, beef cattle, hogs, and sheep—the decision to increase production leads to a decline in current marketings, to increased values of the livestock products involved, and to further decisions to increase production. For these classes of livestock the nature of the production process generates interrelated cycles of numbers of animals on farms, values, and marketings. The length of these cycles is a function of the time required for gestation plus the average age at which the animals are marketed.

3. The most important causes of irregularities in these cycles for the various classes of livestock are as follows:

a) Hogs.—Weather-induced fluctuations in the price of feed (primarily corn) affect the profitability of hog production and impose random-distributed irregularities on the persistent and observable cycle.

b) Sheep.—Fluctuations in the price of feed are of small importance in affecting the sheep cycle because feed costs for the sheep producer are primarily fixed costs which are represented by investment in land. The fact that wool marketings react differently from lamb marketings to

TABLE 9*

SECULAR INCREASE IN THE VARIOUS CLASSES
OF LIVESTOCK, 1890-1944

Class of Livestock	Increase (Millions of Animal Units)	Per Cent of Total Increase in All Animal Units
Milk cows.....	12.5	51.0
Hogs.....	4.0	16.5
Chickens.....	4.0	16.5
"Other cattle".....	3.0	12.0
Sheep.....	1.0	4.0
Total.....	24.5	100.0

* Source: Computed from data from the United States Department of Agriculture.

changes in the profitability of sheep production dampens the amplitude and shortens the length of the cycle.⁵² The presence of foreign and extra-agricultural influences on the prices of wool affects the profitability of sheep production and creates irregularities in the cyclical pattern. The weather seems to have been an important factor only in the case of severe drought, as in 1934.

c) "Other (beef) cattle."—The cycle in cattle numbers has almost no irregularities. The only important deviation in the regular fourteen- to sixteen-year cycle

⁵² This assumes that $\eta < 1$. If $\eta > 1$, the reverse would be true.

occurred during the forced liquidation of the mid-thirties. Feed costs are primarily fixed costs, and no product other than the carcass is of much economic importance. Extra-agricultural influences, such as fluctuations in the level of general business activity, have had a slight modifying effect on the amplitude of the cattle cycle but none on its general pattern.

4. For those classes of livestock which do not require a substantial time lag between the decision to increase production and the marketings resulting from that decision, no cycles are evident.

Milk cows exhibit very slight cyclical variations; poultry, none.

5. Yearly fluctuations in all animal units due to secular trend were relatively unimportant, being only about one-fifth of their average yearly fluctuations. Of the secular trend in all animal units, the trend in the number of milk cows constituted more than 50 per cent.

6. Fluctuations in numbers of animal units on farms have had little effect on the production of feed, while fluctuations in feed production have had a significant, though not a major, effect on fluctuations in numbers of animal units.

CHAPTER IV

A PRODUCTION FUNCTION FOR LIVESTOCK AND LIVESTOCK PRODUCTS

IN THE second chapter of this study an attempt was made to explain the volume of feed consumption in each year. It was seen that the lack of alternative uses for a very large proportion of our feed supplies made these supplies "price-determined" by the prices of the livestock products for which they were a factor of production. The fact that feeds are largely "price-determined" does not mean that the prices of livestock products uniquely determine the prices of feeds but that, given the marginal productivity function of feedstuffs, the prices of livestock products will determine the price of feed for any particular volume of feed supplies. Within the variation in feed supplies which has been experienced in this country, the fact that feeds are price-determined means that the consumption of feed in any year will closely approximate production in the preceding production period. It was further seen that the volume of feed production varied almost entirely because of the weather rather than because of the plans of the farmers.

In the third chapter of this study an attempt was made to show that, with a given consumption of feed, the production of livestock products varies directly with the number of animal units being fed. Following this, an examination of the causes of fluctuations in livestock numbers was made.

A STATEMENT OF THE PROBLEM

Now, to complete the study of fluctuations in the production of livestock and

livestock products, it will be necessary—or at least desirable—to relate quantitatively changes in feed consumption and in livestock numbers to the production of livestock products over the period under consideration. If all things other than feed consumption and numbers of animal units remained constant, a properly conceived correlation analysis which considered only these factors as independent variables would, in the presence of accurate data and logical indexes, explain all the fluctuations in livestock production. All other things did not, however, remain constant. The changes which are relevant for this study and which must be considered in attempting to quantify the relationships involved are certain "technological" changes in the feeding and breeding of livestock. With a given technology of production, feed consumption and the number of animal units fed would determine the volume of production. With the important changes in technology which have taken place in this country during the last thirty-five years, an analysis which did not consider such changes would present less information and be subject to greater misinterpretation than an analysis which considered them. Therefore, in the following correlation analysis the effect of these technological changes has been included by considering "time" as a third independent variable. In the words of Schultz, "time" can justifiably be included in intertemporal analyses as "a catch-all for the resultant of those factors which cannot be measured separate-

ly, but which change more or less slowly and smoothly."¹

Those factors (previously referred to as "technological changes") which are the main determinants of the significance of "time" in the analysis are the development of more productive types of livestock and the improvement of feeding practices. In so far as the evolution of livestock types is the result of a progressive and continual selective breeding process, the influence of such changes will most probably proceed "slowly and smoothly" and hence be peculiarly well suited to measurement by the use of the "time" variable. Similarly, the accretion and dissemination of knowledge concerning calcium-phosphorous and protein ratios, vitamins, mineral needs, and other factors relating to the productive use of feed supplies must proceed "more or less slowly and smoothly." Therefore, the effect of these influences, too, can be measured by the use of "time" as an independent variable. Because "time" seems suited to reflect the influence of these relevant factors other than the volume of feed consumption and the number of animal units, the following analysis will make use of the generalized function

$$X_1 = f(X_2 X_3 X_4),$$

where X_1 is the volume of livestock production per year, X_2 is the volume of feed consumption per year, X_3 is the number of animal units fed per year, and X_4 is "time."²

¹ Henry Schultz, *The Theory and Measurement of Demand* (Chicago: University of Chicago Press, 1938), p. 55.

² It should be noted that any production function—whether of manufacturing or of livestock products—which confines all the numberless *different* factors of production into two or three (or more) indexes and which likewise represents the production of a multiplicity of products by a single index number contains an implicit assumption which can never accord rigorously with reality. Such a function implies that all the various factors of production con-

In selecting the particular function to be used, a linear arithmetic function was considered first. In spite of the obvious logical objections involved in using such a function, it was felt that, over the restricted range of observations in the sample being studied, these objections might be of negligible importance. Thus, the fact that the form of the function implied the possibility of production occurring in the absence of either feed or livestock—a patent absurdity—and that the marginal productivity function of the independent variables was a constant—at variance with the known facts—it was felt that the simplicity of the function might compensate for quantitatively inconsequential deviations from the criteria dictated a priori reasoning. When this function was tried, however, the scatter of the observations gave evidence of marked heteroscedasticity, and a relatively poor fit was obtained. It was decided, therefore, to try a more logically defensible function.

A logarithmic transformation was next tried.³ This function is expressed as

$$\log X_1 = a_{1.234} + b_{12.34} \log X_2 + b_{13.24} \log X_3 + b_{14.23} X_4$$

and seems suitable for several reasons.

tained in a single index are equally efficient (in terms of units of the index) in combining with any of the factors represented by a different index in effecting changes in the index which represents the dependent variable. As was explained in chapter i, the indexes of feed consumption and livestock production were so defined that they would fit this assumption as well as experimental and historical data permit. It is not felt that the deviations of this assumption from reality affect importantly the results and correct interpretations of the statistical section of this study. If the methodology of this chapter were to be applied to particular regions or to particular livestock enterprises, a redefinition of the indexes would be necessary.

³ This type of curve was first used by Cobb and Douglas in their work (C. W. Cobb and P. H. Douglas, "A Theory of Production," *American Economic Review*, Vol. XVIII [March, 1928] [supplement]). As is seen from the equation, a straight line is fitted to the logarithms of the indexes.

First, it is statistically manageable in that the coefficient can be determined by the method of least squares.

Second, the production function will necessarily be concave downward;⁴ that is, the use of additional units of X_2 (or X_3) will yield successively smaller increments in X_1 , assuming that X_3 (or X_2) is fixed. Although it is probable that decreasing returns in this sense do not exist for X_2 in the case of extremely low rates of feeding or for X_3 in the case of extremely heavy rates of feeding, it is almost certain that, over any range of observations which will knowingly be permitted to exist by livestock producers, decreasing returns will be operative. The reasons for this will be discussed in the paragraphs dealing with the marginal productivity of feed and of animal units.

Third, this function gives a logically defensible significance to the coefficients. This significance is more easily seen when the function is re-written

$$X_1 = A X_2^a X_3^b 10^{\gamma x_4}$$

where X_1 is the production of livestock and livestock products, X_2 is feed consumption, X_3 is the number of animal units fed, X_4 is time, A is antilog a 1.234, a is b 12.34, β is b 13.24, and γ is b 14.23. The meaning and implications of the coefficients can be discerned more readily when the function is in this form. It can be seen that the absence of any one of the factors of production would result in no production. The values for a and β take on new meaning. The function is homogeneous of the degree $(a + \beta)$. If this sum is greater than 1 for the data

involved, the indication is that there are increasing returns to scale; that is, a given percentage increase in both feed consumption and the number of animal units being fed would result in a greater percentage increase in the production of livestock products. If the sum of a and β is equal to 1, constant returns to scale are indicated; that is, a given percentage change in both feed consumption and the number of animal units being fed would result in an equal percentage change in the dependent variable—livestock production. If the sum of a and β is less than 1, decreasing returns to scale are indicated. A given percentage change in the independent variables (excluding "time") would result in a smaller percentage change in the dependent variable.

The coefficient γ is significant in that it indicates the magnitude and direction of the trend in technological change. If the coefficient is positive, this trend is positive and indicates that in successive years a greater product can be secured from a given quantity of the productive factors. If this coefficient is negative, a given quantity of feed and a given number of animal units will yield a progressively smaller product in successive years.⁵

At any given time the above function reduces to the form

$$X_1 = A X_2^a X_3^b$$

⁵ The coefficient A has no meaning for this analysis. If it were desired to compare the efficiency with which livestock and livestock products were produced in this country as compared with any other area or country, the relative size of this coefficient for the function relating to the United States and the function relating to the area being compared would indicate the relative efficiency of the two areas. It should be noted that, although changing the base of the index numbers does not affect the value of a or β , such a change would affect the value of A . This value would change so that the ratio of the "new" A to the "old" A would be the same as the ratio of the "new" base of the index numbers to the "old" base.

⁴ At any one time the function reduces to the form $X_1 = A X_2^a X_3^b$ and

$$\frac{\partial X_1}{\partial X_2} = (a - 1)(a) A X_2^{a-1} X_3^b < 0$$

if $a < 1$. For this analysis a must be less than 1, as will be demonstrated later. A similar demonstration for the relationship between X_1 and X_3 is valid.

In terms of this function, the marginal productivity function of feed—that is, the increment in production that will result from the consumption of a marginal unit of feed, *ceteris paribus*—can be expressed as follows:⁶

$$\frac{\partial X_1}{\partial X_2} = \alpha \frac{X_1}{X_2}.$$

Similarly, the marginal productivity function of animal units—that is, the increment in product that will result from the feeding of the marginal animal units, *ceteris paribus*—can be written

$$\frac{\partial X_1}{\partial X_3} = \beta \frac{X_1}{X_3}.$$

Marginal productivity functions of this form will decrease at a decreasing rate, a condition which empirical studies and a priori reasoning have indicated to exist over the range of operations which rational guidance will permit.

It is true that a marginal productivity function like that in the preceding paragraph can never indicate negative marginal productivity for positive values of either X_2 or X_3 . It is also apparent that such negative marginal productivity would eventually exist in reality if successively larger volumes of feed were fed to a fixed number of animal units. Eventually sickness and finally death would result not only in decreasing marginal productivity but in a negative marginal product; that is, eventually the consumption of an additional unit of feed by a fixed number of animals would effect an absolute decrement in production. Similarly, the marginal productivity of an animal unit would eventually become negative as the number of animal units became so great that the fixed quantity of feed would become insuffi-

cient to maintain life. Thus, the marginal productivity function which results from the equation

$$X_1 = A X_2^\alpha X_3^\beta$$

is logically incompatible with the known facts at these extremes of operation. This incompatibility is not significant in any real problem of analysis, however, for the very good reason that such extremely heavy and light rates of feeding are never knowingly permitted to exist and never do exist for any appreciable number of livestock producers. The obvious nonsense of incurring additional costs for the sake of a diminution in output reduces the logical incompatibility in the form of the marginal productivity function to a matter of academic interest rather than one of practical consequence.

The form of this function is at variance with the probable facts in yet another way. It is probable, if not certain, that for very low rates of feeding the marginal productivity of feed increases; that is, the consumption by a fixed number of animals of successive marginal units of feed will yield successively larger increments in the product. If, as was indicated in the preceding paragraphs, negative marginal productivity resulted from very low values of feeding, it most probably follows that the curve of marginal productivity of feed at this level of operations will be rising. In this sense the operations are in a stage of "increasing returns." The marginal productivity function which results from the Cobb-Douglas type of equation can never be other than convex downward⁷ and therefore is never applicable to a

$$^7 \frac{\partial^2 X_1}{\partial X_2^2} = (\alpha - 2)(\alpha - 1)(\alpha) A X_2^{\alpha-2} X_3^\beta > 0$$

if $\alpha < 1$.

Similarly, $\frac{\partial^2 X_1}{\partial X_3^2} > 0$ if $\beta < 1$.

$$^6 \frac{\partial X_1}{\partial X_2} = \alpha A X_2^{\alpha-1} X_3^\beta = \frac{\alpha A X_2^\alpha X_3^\beta}{X_2} = \alpha \frac{X_1}{X_2}.$$

case of "increasing returns" as defined above. It is clear once again, however, that this defect in the equation has little practical significance. No rational producer would produce in this area of increasing returns, if he produced at all. It is extremely unlikely that only n units of feed would be used by a producer if the use of the $n + 1$ unit would yield a greater increment in product than did the use of the n th unit. Similarly, the producer would in almost all cases continue to purchase animals to consume a given feed supply so long as the feeding of each successive animal unit resulted in a progressively greater increment in total product. It is true that costs, other than those involved directly in the purchase or acquisition of feed and/or animal units might, in the short run, make it economically rational to operate in the stage of increasing returns, but it is believed that such cases are rare and can safely be ignored in a problem of macro-analysis such as is here in question.⁸ That the two types of logical incompatibilities mentioned were not important in this problem was indicated by the very much reduced heteroscedasticity of the observations and the improvement in fit when the Cobb-Douglas type function was substituted for the linear arithmetic function. Therefore, for the reasons stated above, this logarithmic transformation of the arithmetic function was adopted in the analysis.

⁸ Although it is almost certain that operations have not been in the stage of increasing returns in this country, it is possible that an appreciable proportion of livestock production in Europe during and immediately after World War II was in the stage of increasing returns for feed. The cost of re-establishing herds of livestock might have been considered to be greater than the cost of merely maintaining such herds without any commercial production of livestock products. The shortage of food and of feed may have made it necessary for many farmers to face these alternatives.

THE FINDINGS

When the linear regression line was fitted to the logarithms of the data, the following coefficients resulted:⁹

$$a_{1.234} = 0.3161$$

$$b_{12.34} = 0.3299 \pm .0296$$

$$b_{13.24} = 0.5230 \pm .0478$$

$$b_{14.23} = 0.0021 \pm .0001$$

The standard error of estimate, the unexplained variance, the multiple correlation coefficient, and coefficient of determination follow:¹⁰

$$\bar{S}_{1.234} = .0167$$

$$\bar{S}_{1.234}^2 = .00028$$

$$\bar{R}_{1.234} = .95402$$

$$\bar{R}_{1.234}^2 = .91083$$

When the deviations of the computed X_1 from the actual X_1 were plotted around the net regression lines for X_1 on X_2 , X_3 , and X_4 , it was seen that the degree of correlation could be improved by substituting concave (downward) curves for the linear regression lines of X_1 on X_2 and X_3 . These curves, conforming with a priori reasoning on the nature of the productive process, resulted in an adjusted index of multiple correlation of .95580 and an adjusted index of determination of .91332.¹¹ It was not felt that a justifiable curve could be fitted to the net regression line of X_1 on X_4 , "time."¹²

⁹ The ranges are equal to twice the respective standard errors of estimate.

¹⁰ All are adjusted for the loss of four degrees of freedom.

¹¹ It was felt that the curve used approximated a section of a parabola and that the loss of one additional degree of freedom was adequate.

¹² The simple linear correlation coefficient between X_2 and X_3 is .798. Although this is clearly significant, it is not felt that the degree of collinearity seriously impairs the value of the analysis which follows.

The contribution of the independent variables, in terms of the curved regression lines for X_2 and X_3 and a linear regression line for X_4 , to the determination of livestock production is shown graphically in Figure 28. From this figure it can be seen that the equation explains fluctuations in actual livestock production with a high degree of accuracy after 1925, with the exception of the year 1934. In this year the deficiency of the index of feed consumption becomes apparent. It will be remembered that this index did not include certain roughages, such as the straws of the small grains, because of the lack of adequate data. In the year 1934, when the usual sources of feeds, such as corn, hay, and pasture, were available only in severely reduced quantities, recourse was had to straw stacks, corn stover, and other feeds which conventionally were used only to a slight extent for feed and were used to a much greater degree for bedding and other purposes or were wasted. Undoubtedly the index of feed consumption understates actual consumption in 1934 and consequently caused the computed index of livestock production to be substantially below actual production (Fig. 28).

In regard to the period 1910-25, when the computed index of production is significantly different from actual production, a different explanation can reasonably be offered. The index of animal units fed was available only from 1919 to 1944. This index was extended back to 1910 on the basis of the relationship which existed from 1919 to 1944 between animal units on farms on January 1 and the number of animal units fed in the corresponding feeding years. Extrapolation of any index on the basis of a relationship which existed in a different period with necessarily different condi-

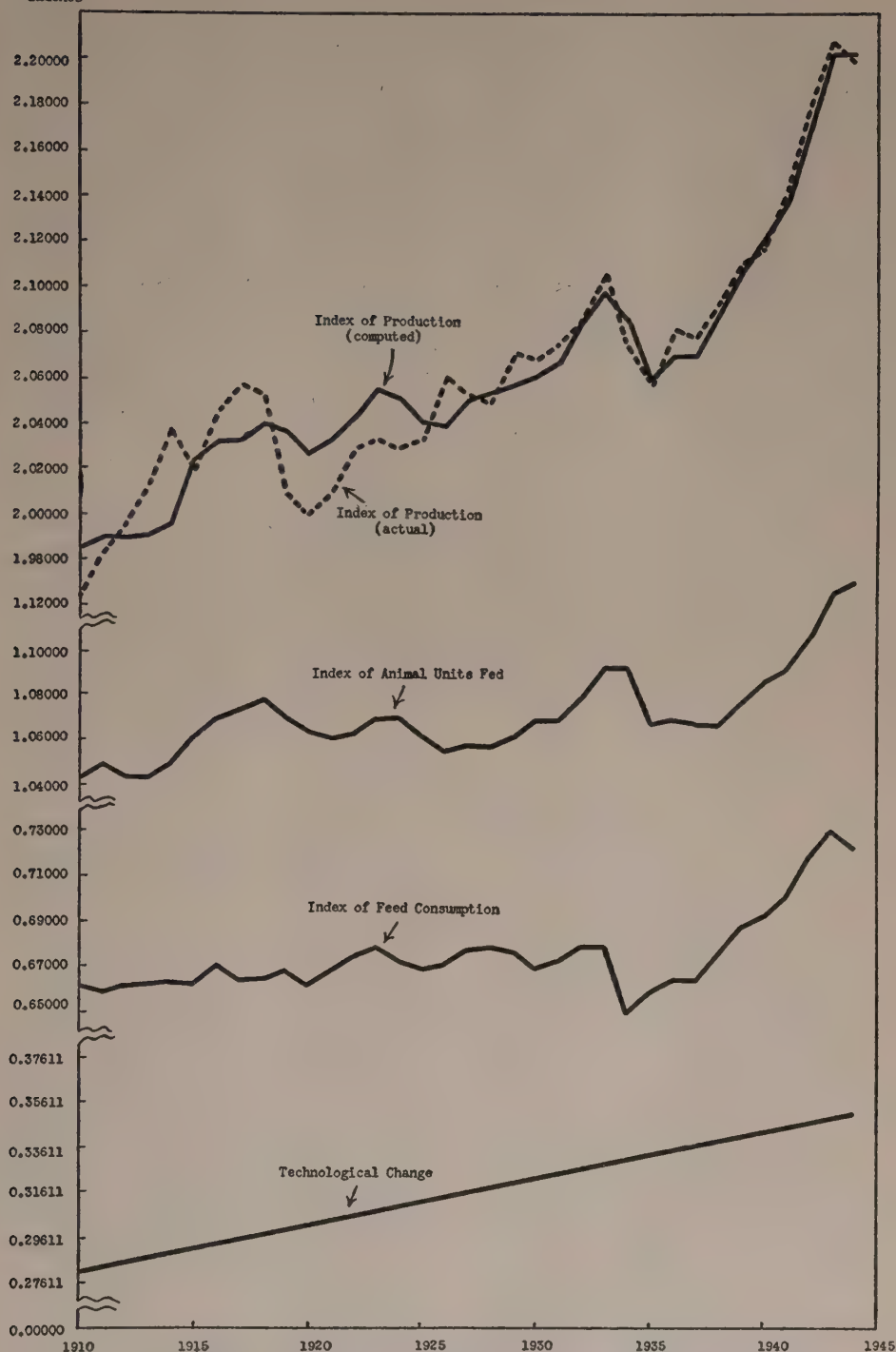
tions is, of course, a risky procedure. It was felt that the risk was justified in this case, although the decision to do so may be responsible for the deviations between the actual and the computed index of production. If the period covered had been limited to 1919-44, it would have been possible to eliminate almost all the deviations. The fact that the computed index was consistently below the actual index from 1912 to 1918 and was consistently above the actual index for the contiguous period 1919-25 prevented the fitting of a justifiable curve to the data to eliminate these divergences. If the period considered had not gone back of 1919, it would have been possible to make the conformance of the computed to the actual index much closer by using a more sharply curved regression line of X_1 , on X_2 and on X_3 .

The type of curve used in these net regression lines need not have been altered; only the degree of curvature need have been changed. Thus, the use of questionable data from 1910 to 1919 for animal units fed could have caused the relative failure of the equation to explain actual livestock production for the period 1910-25. Theoretically, of course, the inclusiveness of the independent variables would permit an almost complete determination of livestock production. The equation does account for over 90 per cent of the variation in actual production. It is felt that the failure to account more completely for fluctuations in production can be justifiably assigned to the described imperfections in the indexes for the period 1910-19 and for the year 1934.

The sum of the coefficients α and β is about 0.85. This implies that a simultaneous proportionately equal change in feed consumption and in the number of animal units fed would result in a

Proportionate Contributions of Animal Units, Feed Consumption, and Technological Change
in Determining the Volume of Production of Livestock and Livestock Products, 1910-44

Logarithm of
Indexes



These three factors, in terms of the given equation, explained fluctuations in livestock production with a high degree of accuracy from 1925 to 1944. The relative inaccuracy in the earlier period is explicable by the inaccuracy of the data.

FIG. 28

corresponding proportionate change in livestock production 0.85 per cent as great. A doubling of feed consumption and of the number of animal units being fed, for instance, could be expected to result in an increase in livestock production of 85 per cent. That this is a reasonable expectation is evident. Feed and animals constitute at any one time only two types of factors of production. They are the only two types included in the analysis because they are the only factors with important yearly fluctuations. Also of importance at any one time as factors of production, however, are the labor of farmers and the physical facilities for effecting the breeding and feeding of livestock and for the securing of livestock products such as milk and eggs. The application of increasing "quantities" of variable factors of production—feed and animals, in this case—to factors of production that are fixed in supply or are varied to a lesser degree—labor and physical facilities—can be expected, according to familiar Ricardian doctrine, to yield successively smaller increments in output. It is not surprising, therefore, that the doubling of the variable factors of production (feed and animals) will result according to the equations in an increase of only about 85 per cent in livestock production.¹³ That the values of a

¹³ The equation is illogical in another sense which is of little consequence. The form of the equation implies that a doubling of both X_2 and X_3 would increase X_1 by 85 per cent; that a quadrupling of X_2 and X_3 would increase X_1 by 240 per cent; and that subsequent simultaneous increases in X_2 and X_3 would cause subsequent percentage increases in X_1 , which were 85 per cent as great as the increases in X_2 and X_3 . It is clear that if such increases in X_2 and X_3 were carried to extremes and other factors of production remained constant, cows would remain unmilked, disease would increase, and many animals would be without adequate shelter, etc. As a consequence of these potential deficiencies in the labor supply and physical facilities, the increases in X_2 for

and β which yield such results have been obtained from the indexes in this study tends to increase the confidence with which the indexes can be used. If the sum of a and β had been greater than 1, the implied significance would have been that the doubling of the volume of feed consumed and of the number of animals being fed would result in more than doubling the production of livestock and livestock products. Such a result would be counter to all established economic theory and would raise serious doubts as to the validity of the data and the methods used.

The value of the coefficient representing technological trend was $+0.0021$.¹⁴ Each year a given quantity of feed and a given number of animal units could be expected to yield 0.2 per cent more livestock products. A given quantity of feed and a given number of animal units would produce in 1944 approximately 7.3 per cent more livestock and livestock products than in 1910.

The index of animal units on farms rose during the thirty-five-year period at a rate of 0.60 per cent per year. The index of feed consumption rose at a rate of 1.08 per cent per year. Consequently, there was a tendency toward heavier

very large increases in X_2 and X_3 would undoubtedly be less than that which the use of the coefficients a and β would indicate. Since, however, the average yearly percentage fluctuation in the indexes of feed consumption and animal units fed was less than 5 per cent—the fluctuations never being as great as 20 per cent and exceeding 10 per cent in only three years—it was felt that the adaptability of the farm labor supply and of physical facilities used in livestock production was great enough to make this sort of objection to the equation of slight consequence.

¹⁴ For the sake of ease in computation, each unit of t was equal to one one-hundredth of a year. The value of the computed coefficient was $+0.2090$. When each unit of t is equal to 1 year, the value of the coefficient becomes $+0.0021$ as indicated above.

rates of feeding through the years.¹⁵ It has been said that, within the range of operations existing under rational direction, the productivity functions of the factors of production will be increasing at a decreasing rate. In the light of this postulate, the increased rates of feeding could be expected to result in a decrease in the output of livestock products per unit of feed consumption, *ceteris paribus*. In the presence of the technological changes which the correlation analysis has shown to have existed, the increased rates of feeding would be expected to result in an increase in the production of livestock products per unit of feed consumption that was less than the increase in efficiency in the use of feed which resulted from the technological changes. This expectation is confirmed by the data. Whereas the increase in efficiency was at the rate of 0.2 per cent per year, the increase in the production of livestock products per unit of feed consumption was at the rate of only .095 per cent

¹⁵ There are several factors contributing to the tendency toward heavier rates of feeding. Probably one of the most important is the increase in the number of cost analyses by the state colleges of agriculture, revealing that a more economic use of resources frequently results from using labor and capital more intensively than often has been the case. The increasing costliness of farm labor has undoubtedly reinforced the lessons of these analyses and has encouraged farmers to raise the marginal productivity of labor at the expense of lowering that of feed. A second factor is the tendency to market animals at earlier ages. In order to get young animals that are still growing fat enough for market, heavier rates of feeding are required than when mature animals are being readied for market. Third, the development of animals that can utilize greater quantities of feed relatively efficiently has also been of importance in causing farmers to feed at heavier rates. Modern types of dairy cattle, for instance, are able to consume and use efficiently more feed than was the case before the widespread work of state colleges and dairy herd improvement associations in improving breeding practices.

per year (Fig. 29).¹⁶ Thus, the tendency to feed at heavier rates partially counteracted the effect of technological change in increasing the output of livestock per unit of feed consumption.

Conversely, the tendency toward heavier rates of feeding would lead one to expect that the production of livestock products per animal unit has increased more rapidly than did efficiency as represented by the coefficient γ . The data again confirm the expectation. Livestock production per animal unit increased at a rate of 0.6 per cent per year as contrasted with the increase of 0.2 per cent per year in efficiency (Fig. 30).

As to the significance of the relative magnitudes of α and β , no simple explanation can be given. It has been stated that the marginal productivity function of feed is

$$\frac{\partial X_1}{\partial X_2} = \alpha \frac{X_1}{X_2}.$$

The marginal productivity function of animal units is

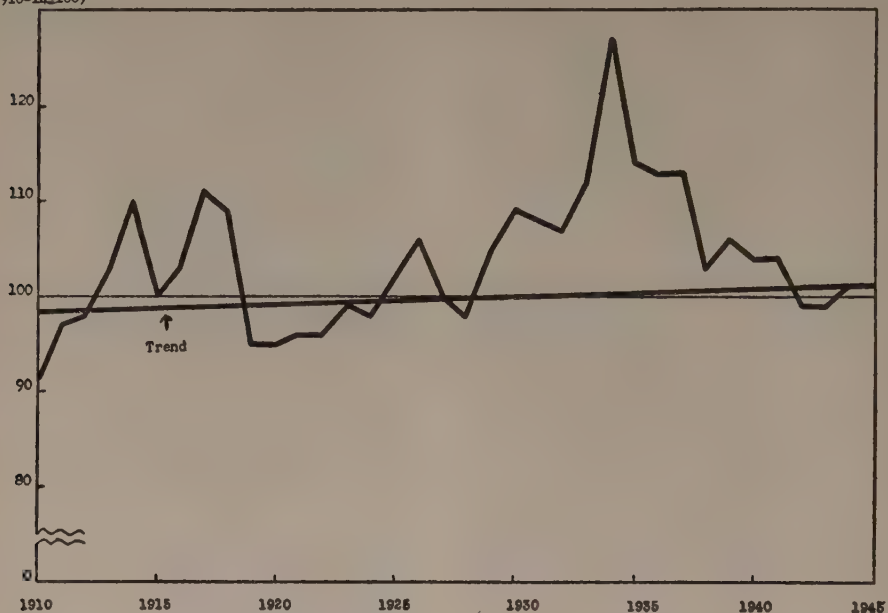
$$\frac{\partial X_1}{\partial X_3} = \beta \frac{X_1}{X_3}.$$

It can be seen that, the larger the value of α , the larger the marginal product of X_2 (feed) for any given level of X_3 (animal units). Similarly, the magnitude of the marginal product of X_3 , for any given level of X_2 , varies directly with β . It is not very meaningful, however, to compare directly the magnitudes of α and β and to conclude from such a comparison that the influence of changes in feed consumption is more "important" or more "significant" than the in-

¹⁶ The year 1934 was not included in the computation of the trend because of the previously described inaccuracy in the index of feed consumption for that year.

Ratio of the Index of Production of Livestock and Livestock Products to the Index of Feed Consumption, 1910-44

Index
(1910-44=100)

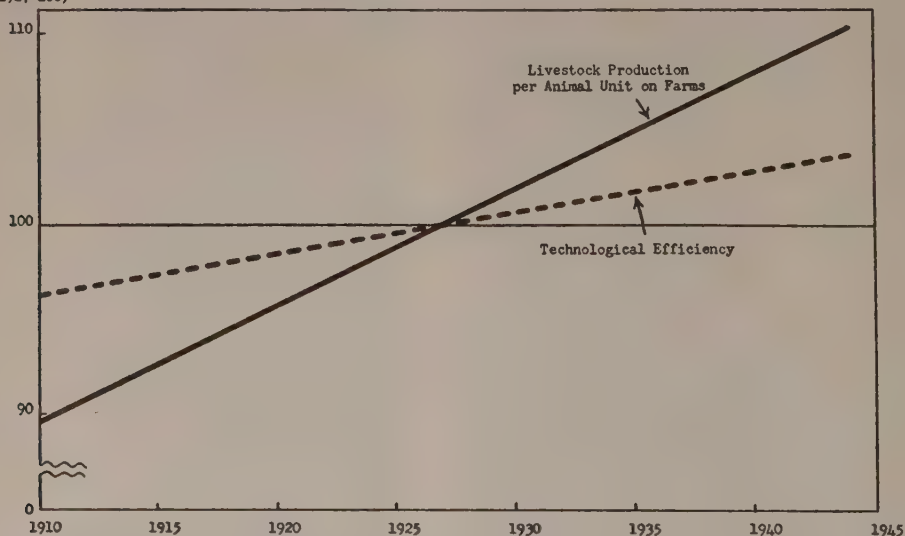


This ratio increased at a rate of 0.095 per cent per year.

FIG. 29

Livestock Production per Animal Unit on Farms and Changes
in Technological Efficiency in Livestock Production, 1910-44

Index
(1927=100)



The markedly greater rapidity in the rise in livestock production per animal unit is attributable to increased rates of feeding.

FIG. 30

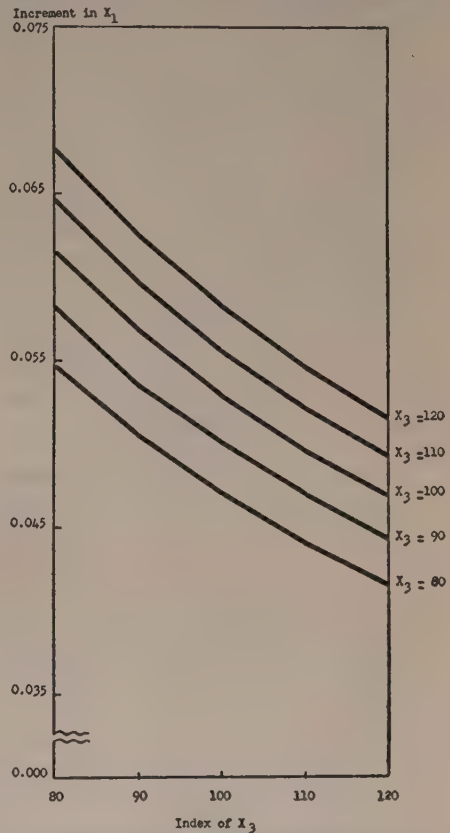
fluences of changes in animal units or that the reverse is true. These coefficients are helpful in that they permit the construction of so-called "production contour maps." By the use of these maps it is possible to determine the effect on production of any variation in any of the factors of production for any given "quantity" of the other factor or factors of production. In this problem the construction of such maps will reveal the effect on livestock production of changes in feed consumption for various levels of the livestock population and the effect of fluctuations in animal numbers for various levels of feed consumption.

The production contour map for feed consumption is shown in Figure 31.¹⁷ Probably the most striking thing about the marginal productivity of feed within the range of observations indicated is the low magnitudes of the marginal products. When the index of animal units was held constant at 80 (1910-44 = 100), the consumption of a marginal unit of feed when that index was 80 raised the index of livestock production approximately one-twentieth as much as the increase in the index of feed consumption (Fig. 31). When the index of feed consumption was 120 and that of animal units 80, a marginal increase in feed consumption resulted in raising that index of production only about one twenty-fifth as much. The marginal products were, of course, much greater when the index of animal units was held constant at 120. In this case a marginal increase in the index of feed consumption from 80 resulted in increasing livestock production over one-sixteenth as much.

The production contour map for ani-

mal units reveals that for animal units, too, the marginal products resulting from the use of additional animals with no change in feed consumption were, over the range of operations found in

Production Contour Map for Feed Consumed by Livestock, 1910-44



This map indicates that American agriculture operated in the period 1910-44 in such a way that increased feed consumption typically resulted in only a slight increase in livestock production, animal units being unchanged.

FIG. 31

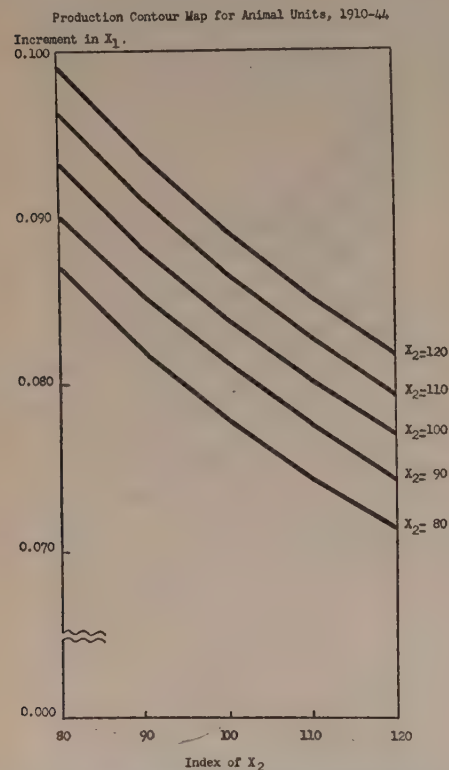
this country, small (Fig. 32). The range of marginal products is found in Table 10.

It can be seen that the same pattern exists for the marginal products of animal units as existed for units of feed consumption. The difference in magnitude between the α and β coefficients is seen in the relatively larger marginal products for animal units for corresponding

¹⁷ These curves were drawn by use of the following equation:

$\log y = \log A' + \beta \log X_3 + (\alpha - 1) \log X_2$,
where $A' = A + a$.

magnitudes of the two indexes. Thus, when both indexes were 80, the marginal products of an animal unit was 0.087 as compared with a marginal product for a unit of feed consumption of 0.055. The ratio of these marginal products equals the ratio of α to β .



The marginal products have been small for agriculture in the United States between 1910 and 1944, though the marginal products for animal units are larger than the corresponding products for feed.

FIG. 32

The fact that these marginal products for feed and for animal units were small, being less than 0.1 for the whole range of observations included in any fluctuations of the two indexes from 80 to 120, deserves examination. Saying that these marginal products are small is merely an oblique way of saying that the range of observations included lies within those

sections of the productivity curves which are approaching fairly closely the horizontal. The productivity curves for both feed and animal units must, of course, be of the type indicated in Figure 33.

The smallness of the marginal products indicates simply that this country's livestock economy has operated within a range embracing the more nearly horizontal section of the productivity curves. As a consequence, if the indexes of feed consumption and of animal units were both at 100, an increase in feed consumption of 1 per cent would increase production only about 0.05 per cent, and an increase of 1

TABLE 10
INDEX OF FEED CONSUMPTION

INDEX OF ANIMAL UNITS	MARGINAL PRODUCT		
	80*	100*	120*
80.....	0.087	0.093	0.099
100.....	.078	.084	.089
120.....	0.071	0.077	0.082

* Index of animal units.

per cent in the index of animal units would increase production only about 0.08 per cent. A simultaneous increase of 1 per cent in both indexes would, on the other hand, increase production about 0.85 per cent. It must be remembered that the order of magnitudes of the marginal products would change radically if the range of observations were to be substantially extended. The marginal productivity curves increase at an increasing rate as the ratio of the variable to the fixed factors of production decreases. At some ratio, beyond the realm of probability for aggregates such as are here being considered, an increase in the variable factor would undoubtedly result in an increment in the product of much greater proportionate magnitude. As the

ratio of the index of the variable factor to the index of the fixed factor approaches zero, the marginal product of the variable factor increases rapidly; conversely, as the ratio of the variable to the fixed factor of production increases beyond the range indicated in Figures 30 and 31, the marginal product quickly approaches zero.

The actual range of observations in this country between 1910 and 1944 was not so great as that included in Figures 31 and 32. As might be expected, the most marked disparities between the indexes of feed consumption and of animal units fed occurred during the drought of the 1930's and during World War II. For the feeding year 1933-34 the index of animal units fed was 122, while that of feed consumption was only 94. The former index was about 30 per cent greater than the latter. In World War II the index of feed consumption, under the impetus of successive bumper crops and the liquidation of government-financed swollen inventories of feed grains, rose to 152 in 1942 and to 164 in 1943. In these two years the index of feed consumption was about 16.5 per cent greater than that of animal units fed. In all other years between 1910 and 1944 the indexes never had differences greater than 10 per cent. Therefore, it seems safe to say that the marginal products of feed and of animal units have been typically, for the United States, of the order of the magnitudes indicated.

Production contour maps such as have been constructed for national aggregates of livestock production, feed consumption, and animal units fed can be constructed with greater immediate usefulness, perhaps, for individual livestock enterprises or for any of the several classes of livestock. By controlled experiments it should be possible to devise such

schedules of marginal productivity for the various conditions that exist in the different regions and with varying physical facilities. Such a procedure would enable the individual livestock producer to equate more nearly with knowledge, rather than with crude observation or intuition, marginal cost and marginal revenue. The construction of such maps for various classes of livestock enterprises on either a national or a regional basis might prove helpful to meat packers, processors, and others to whom the successful prediction of future production means economic reward. The use of this statistical approach might, for in-

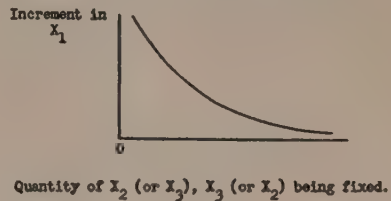


FIG. 33

stance, enable meat packers to make better use of estimates of corn production and of pig crops in forecasting the volume of pork production. The application of the generalized approach of this study to particular problems such as these should not involve many difficulties and should make the overcoming of these difficulties, whatever they might be, economically worth while.¹⁸ It is also suggested that the methodology of this study might be useful for governmental agencies charged with responsibility for stabilizing or controlling for some other objective the volume of this country's livestock production. It is clear that a society whose income is created primarily by nonagricultural enterprises can

¹⁸ Deficiencies in the basic data would be of more importance in any attempt to solve particular problems than in an attempt to establish methodology.

achieve almost any level of livestock production that is desired. If social cost were ignored, animals and feed could be imported to raise greatly the volume of production, and livestock production could be diminished by diverting resources to other uses through appropriate taxation or subsidization. Governmental regulation of various sectors of the economy is often justified on the grounds that specialized economists and political scientists are more competent than ordinary agricultural or industrial entrepreneurs in appraising the consequences of available economic alterna-

tives. Although the centralized planning that has been experienced in this country, in the agricultural sphere at least, makes one hesitant to accept the validity of such a hypothesis—witness, for example, the experience of the Federal Farm Board and of the Commodity Credit Corporation—and although it is certain that this argument can never be documented, it is hoped that the use of tools such as are devised in this study may to some extent enable centralized planning authorities to determine more precisely the immediate allocational effects of their decisions.

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APPENDIX

TABLE A*

INDEX OF FEED SUPPLIES BY CROP YEARS, UNITED STATES, 1910-44

(Millions of Feed Units)†

Year	Corn	Oats	Barley	Grain Sorghums	All Hay	Oilseed Meal and Cake	Wheat Mill-feeds	Total‡	Index of Total (1910-14 = 100)
1910.....	85	18	4	2.3	36	2.5	5.3	153	103
1911.....	75	15	4	1.6	32	3.3	4.4	136	91
1912.....	85	20	5	2.7	39	3.2	6.4	162	109
1913.....	70	18	4	1.9	38	3.1	6.4	142	95
1914.....	74	17	4	2.2	39	3.8	10.3	150	101
1915.....	83	22	5	2.9	44	3.0	11.7	171	115
1916.....	72	20	4	1.4	49	3.0	4.5	154	103
1917.....	83	22	4	1.6	42	2.8	4.5	160	107
1918.....	75	23	6	1.9	40	2.9	10.1	159	106
1919.....	78	19	4	3.1	43	3.2	10.8	161	108
1920.....	92	33	4	3.5	44	2.9	8.4	177	119
1921.....	94	21	4	2.9	44	2.1	8.1	176	118
1922.....	83	19	4	2.0	46	2.7	8.1	165	111
1923.....	83	19	4	2.3	44	2.9	6.2	161	108
1924.....	66	22	4	2.5	45	3.3	8.1	151	101
1925.....	81	24	5	2.3	40	4.4	4.9	161	108
1926.....	79	20	4	2.8	37	4.1	4.8	152	102
1927.....	79	18	6	3.3	48	3.5	4.9	162	109
1928.....	77	20	7	3.1	44	3.9	5.0	160	107
1929.....	75	18	7	2.1	43	3.9	4.9	154	103
1930.....	62	18	7	1.6	38	3.8	5.0	136	91
1931.....	77	19	5	2.9	37	3.3	4.5	149	100
1932.....	90	13	7	2.8	42	3.3	4.4	163	109
1933.....	78	10	4	2.1	40	3.2	4.2	141	95
1934.....	51	18	3	1.0	31	3.5	4.4	112	75
1935.....	67	18	7	2.5	44	4.2	4.6	148	99
1936.....	50	15	4	1.4	39	4.5	4.7	118	79
1937.....	76	18	6	2.5	41	5.4	4.4	154	103
1938.....	82	18	7	2.5	48	5.3	4.6	168	114
1939.....	89	17	7	2.1	47	6.2	4.5	173	116
1940.....	88	19	7	3.3	50	6.8	4.7	179	120
1941.....	93	19	8	4.0	50	6.9	4.5	185	124
1942.....	102	23	10	3.9	55	9.2	5.1	208	140
1943.....	95	20	7	3.7	53	9.5	5.3	194	130
1944.....	97	20	7	6.2	51	9.2	5.9	196	132

* Source: Computed from data of the Bureau of Agricultural Economics, United States Department of Agriculture.

† 1 ton of corn = 1 feed unit.

‡ The figures given above were not carried out to as many places as were the actual computations. Consequently, the totals may differ slightly from the sums of the figures here presented.

TABLE B*
INDEX OF STOCKS OF FEED ON FARMS BY CROP YEARS
UNITED STATES, 1910-44
(Millions of Feed Units)†

Year	Corn	Oats	All Hay	Total‡	Index of Total (1910-14 = 100)
1910.....	53	22	5	80	108
1911.....	54	24	4	82	111
1912.....	29	11	3	43	58
1913.....	60	39	6	105	142
1914.....	34	21	4	59	80
1915.....	42	18	5	65	88
1916.....	37	39	6	82	111
1917.....	15	17	6	38	51
1918.....	71	27	5	103	140
1919.....	31	35	4	70	95
1920.....	55	18	4	77	104
1921.....	117	64	7	188	255
1922.....	70	36	4	110	149
1923.....	28	24	5	57	77
1924.....	39	21	5	65	88
1925.....	22	36	6	64	87
1926.....	79	37	4	120	163
1927.....	78	24	4	106	143
1928.....	26	16	6	48	65
1929.....	41	26	4	71	96
1930.....	39	22	4	65	88
1931.....	47	25	4	76	103
1932.....	76	22	4	102	138
1933.....	108	33	5	146	198
1934.....	95	18	4	117	159
1935.....	18	11	2	31	42
1936.....	49	40	6	95	129
1937.....	18	13	3	34	46
1938.....	101	29	6	136	184
1939.....	164	28	8	200	271
1940.....	193	21	5	219	297
1941.....	181	31	6	218	295
1942.....	138	27	5	170	230
1943.....	103	34	6	143	194
1944.....	60	27	5	92	125

* Source: Computed from data of the Bureau of Agricultural Economics, United States Department of Agriculture.

† 0.1 ton of corn = 1 feed unit.

‡ The figures given above were not carried out to as many places as were the actual computations. Consequently, the totals may differ slightly from the sums of the figures here presented.

TABLE C*
INDEX OF FEED CONSUMPTION BY LIVESTOCK (EXCLUDING HORSES AND
MULES), UNITED STATES, 1910-44

Year	All Grains†	Hay‡	Concen- trates Other than Grains§	Pasture and Range	Total|| (All Grains, Hay, and Concentrates Less Amount Fed to Horses and Mules)	Index of Total Amount (1910-14 = 100)
1910.....	81	36	20	26	91	101
1911.....	85	31	23	23	89	99
1912.....	83	31	24	27	91	101
1913.....	87	34	21	24	90	100
1914.....	77	34	25	26	89	99
1915.....	83	36	26	28	96	107
1916.....	89	41	21	26	97	108
1917.....	81	42	24	24	93	103
1918.....	89	37	24	23	94	104
1919.....	88	37	22	26	95	106
1920.....	91	37	17	26	92	102
1921.....	97	39	16	25	95	106
1922.....	94	40	20	26	100	111
1923.....	94	41	20	26	103	114
1924.....	92	41	20	24	98	109
1925.....	85	38	25	23	95	106
1926.....	90	36	21	24	97	108
1927.....	90	37	24	26	102	113
1928.....	93	41	20	25	103	114
1929.....	90	40	20	24	101	112
1930.....	83	37	24	22	96	107
1931.....	83	34	27	23	99	110
1932.....	95	35	21	24	103	114
1933.....	94	36	20	24	103	114
1934.....	68	34	25	19	85	94
1935.....	62	32	26	27	90	100
1936.....	75	37	24	22	94	104
1937.....	67	35	26	25	94	104
1938.....	80	37	24	26	105	117
1939.....	84	42	26	26	110	122
1940.....	85	43	24	28	113	126
1941.....	91	44	26	30	121	134
1942.....	107	46	30	32	139	152
1943.....	124	48	34	29	148	164
1944.....	112	47	35	28	140	156

* Source: Computed from data of R. D. Jennings, Malcolm Clough, and others in the Bureau of Agricultural Economics, United States Department of Agriculture.

† Corn, oats, barley, grain sorghum, wheat, and rye.

‡ Includes all tame and wild hay.

§ Includes oilseed meals and cakes, animal protein feeds, plant by-product feeds, etc.

|| Consumption of pasture and ranges added to consumption of all other feed, multiplied by a factor, 0.63.

TABLE D*
INDEX OF ANIMAL UNITS ON FARMS, JANUARY 1 (EXCLUDING HORSES AND
MULES), WEIGHTED ACCORDING TO CONSUMPTION OF ALL FEED
UNITED STATES, 1867-1945

(Millions of Animal Units)

Year	Milk Cows (Wt. 1.0)	Other Cattle (Wt. 0.7)	Hogs (Wt. 0.3)	Sheep and Lambs (Wt. 0.125)	Chickens (Wt. 0.019)	Total†	Index of Total (1910-14 = 100)
1867.....	8	14	10	6	5	43	57
1868.....	9	15	10	6	5	45	59
1869.....	9	15	10	5	5	44	58
1870.....	10	15	10	5	5	45	59
1871.....	10	15	11	4	5	45	59
1872.....	10	16	12	4	5	47	62
1873.....	10	16	12	5	5	48	63
1874.....	11	17	11	5	5	49	64
1875.....	11	18	11	5	5	50	66
1876.....	11	18	11	5	5	50	66
1877.....	11	18	12	5	5	51	67
1878.....	11	20	13	5	5	54	71
1879.....	11	21	13	5	5	55	72
1880.....	12	22	13	6	5	58	76
1881.....	12	23	13	6	5	59	78
1882.....	12	24	13	6	5	60	79
1883.....	13	25	13	6	5	62	82
1884.....	13	26	14	6	5	64	84
1885.....	13	27	14	6	5	65	86
1886.....	13	29	14	6	5	67	88
1887.....	14	30	13	6	5	68	89
1888.....	14	31	13	5	5	68	89
1889.....	15	31	14	5	5	70	92
1890.....	15	32	14	5	5	72	95
1891.....	15	32	14	6	5	72	95
1892.....	15	30	14	6	5	70	92
1893.....	15	28	13	6	5	67	88
1894.....	15	26	14	6	5	66	87
1895.....	15	25	14	6	6	66	87
1896.....	15	24	15	5	6	65	86
1897.....	15	25	15	5	6	66	87
1898.....	16	26	16	5	6	69	91
1899.....	16	28	16	6	6	72	95
1900.....	17	30	15	6	6	74	97
1901.....	17	32	15	6	6	76	100
1902.....	17	33	14	6	6	76	100
1903.....	17	34	14	6	6	77	101
1904.....	17	34	16	6	6	79	104
1905.....	18	34	16	6	6	80	105
1906.....	18	33	16	6	6	79	104
1907.....	19	32	17	6	6	80	105
1908.....	19	30	17	6	6	78	103
1909.....	19	29	16	6	6	76	100
1910.....	19	29	14	6	7	75	99
1911.....	19	27	17	6	7	77	101
1912.....	20	25	17	6	7	75	99
1913.....	20	26	16	6	7	75	99
1914.....	20	27	16	5	7	76	100
1915.....	20	31	17	5	7	81	107
1916.....	21	32	18	5	7	84	111
1917.....	21	35	17	5	7	86	113
1918.....	22	36	19	5	7	89	117
1919.....	22	35	19	5	7	89	117

* Source: Computed from data of the Bureau of Agricultural Economics, United States Department of Agriculture.

† The figures given above were not carried out to as many places as were the actual computations. Consequently, the totals may differ slightly from the sums of the figures presented above.

TABLE D—*Continued*

Year	Milk Cows (Wt. 1.0)	Other Cattle (Wt. 0.7)	Hogs (Wt. 0.3)	Sheep and Lambs (Wt. 0.125)	Chickens (Wt. 0.019)	Total†	Index of Total (1910-14 = 100)
1920.....	21	34	18	5	7	87	114
1921.....	21	34	18	5	7	85	112
1922.....	22	33	18	5	8	85	112
1923.....	22	32	21	5	8	88	116
1924.....	22	31	20	5	8	86	113
1925.....	23	28	17	5	8	82	108
1926.....	22	27	16	5	8	79	104
1927.....	22	25	17	5	9	79	104
1928.....	22	25	19	6	9	81	107
1929.....	22	26	18	6	9	81	107
1930.....	23	27	17	7	9	83	109
1931.....	24	27	17	7	9	84	111
1932.....	25	29	18	7	8	87	114
1933.....	26	31	19	7	8	92	121
1934.....	27	33	18	7	8	94	124
1935.....	26	30	12	7	7	83	109
1936.....	25	31	13	6	8	83	109
1937.....	25	29	13	6	8	82	108
1938.....	24	29	14	6	7	81	107
1939.....	25	29	15	6	8	84	111
1940.....	25	30	18	7	8	90	118
1941.....	25	32	16	7	8	90	118
1942.....	26	34	18	7	9	96	126
1943.....	27	36	22	7	10	102	136
1944.....	28	37	25	7	10	107	141
1945.....	28	38	18	6	9	99	130

TABLE E*
INDEX OF ANIMAL UNITS (EXCLUDING HORSES AND MULES)
FED ON FARMS BY FEEDING YEARS (OCTOBER 1-
SEPTEMBER 30), UNITED STATES, 1910-44

YEAR	ANIMAL UNITS FED		YEAR	ANIMAL UNITS FED	
	Number (Millions of Units)	Index (1910-14 = 100)		Number (Millions of Units)	Index (1910-14 = 100)
1909-10.....	64	99	1927-28.....	68	105
1910-11.....	65	101	1928-29.....	69	107
1911-12.....	64	99	1929-30.....	72	111
1912-13.....	64	99			
1913-14.....	65	101	1930-31.....	72	111
1914-15.....	69	107	1931-32.....	75	116
1915-16.....	72	111	1932-33.....	79	122
1916-17.....	73	113	1933-34.....	79	122
1917-18.....	74	115	1934-35.....	71	110
1918-19.....	72	111	1935-36.....	72	111
1919-20.....	70	108	1936-37.....	71	110
			1937-38.....	71	110
1920-21.....	69	107	1938-39.....	74	115
1921-22.....	70	108	1939-40.....	77	119
1922-23.....	72	111			
1923-24.....	72	111	1940-41.....	79	122
1924-25.....	69	107	1941-42.....	84	130
1925-26.....	67	104	1942-43.....	91	141
1926-27.....	68	105	1943-44.....	93	144

* Source: Bureau of Agricultural Economics, United States Department of Agriculture.

TABLE F*
INDEX OF PRODUCTION OF LIVESTOCK AND LIVESTOCK PRODUCTS
UNITED STATES, 1910-44

Year	Cattle and Calves†	Hogs‡	Sheep and Lambs§	Chickens||	Turkeys¶	Milk**	Egg††	Total Production‡‡	Index to Total Pro- duction (1910-14 = 100)
1910.....	179	56	15	11	.....	72	18	351	92
1911.....	179	60	15	11	.....	73	19	357	96
1912.....	193	56	15	11	.....	74	19	368	99
1913.....	206	56	15	11	.....	75	19	382	103
1914.....	220	60	15	11	.....	78	19	403	109
1915.....	206	65	15	11	.....	79	20	396	107
1916.....	220	65	15	11	.....	80	19	410	111
1917.....	234	60	15	11	.....	81	19	420	114
1918.....	220	70	15	11	.....	82	19	417	113
1919.....	179	65	15	11	.....	82	21	373	101
1920.....	165	65	15	11	.....	84	20	360	97
1921.....	179	65	15	11	.....	87	21	378	102
1922.....	179	79	15	11	.....	90	22	396	107
1923.....	179	79	15	11	.....	93	23	400	108
1924.....	179	70	15	11	.....	99	23	397	107
1925.....	179	65	31	11	.....	101	23	410	108
1926.....	179	70	31	17	.....	103	25	425	115
1927.....	165	74	31	17	.....	105	26	418	113
1928.....	165	74	31	11	.....	107	26	414	112
1929.....	179	74	31	17	.....	110	25	436	118
1930.....	179	70	31	17	.....	111	26	434	117
1931.....	179	79	31	11	.....	114	26	440	119
1932.....	193	74	31	17	.....	115	24	454	122
1933.....	206	79	31	17	.....	116	24	473	128
1934.....	206	56	31	11	.....	113	23	440	119
1935.....	193	51	31	11	.....	112	23	421	114
1936.....	193	60	31	17	.....	113	23	437	118
1937.....	193	60	31	11	.....	113	25	433	117
1938.....	193	65	31	17	.....	118	25	449	121
1939.....	206	79	31	17	.....	119	26	478	129
1940.....	220	79	31	17	.....	122	27	496	131
1941.....	234	84	31	17	.....	128	28	522	139
1942.....	248	98	31	17	5	132	32	563	151
1943.....	261	126	31	17	5	131	32	603	163
1944.....	261	102	31	17	5	134	36	586	158

* Source: Computed from data of the Bureau of Agricultural Economics, United States Department of Agriculture.

† Weighted liveweight production: pound = 13.75.

‡ Weighted liveweight production: pound = 4.65.

§ Weighted liveweight production: pound = 15.25.

|| Weighted liveweight production: pound = 5.54.

¶ Weighted liveweight production: pound = 5.18.

** Production in 3.5 per cent butterfat equivalent: pound = 1.11.

†† Production in billions of eggs: egg = 0.67.

‡‡ The figures given above were not carried out to as many places as were the actual computations. Consequently, the totals may differ slightly from the sums of the numbers here presented.

